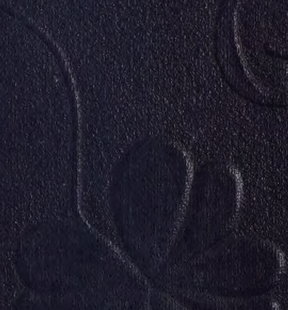
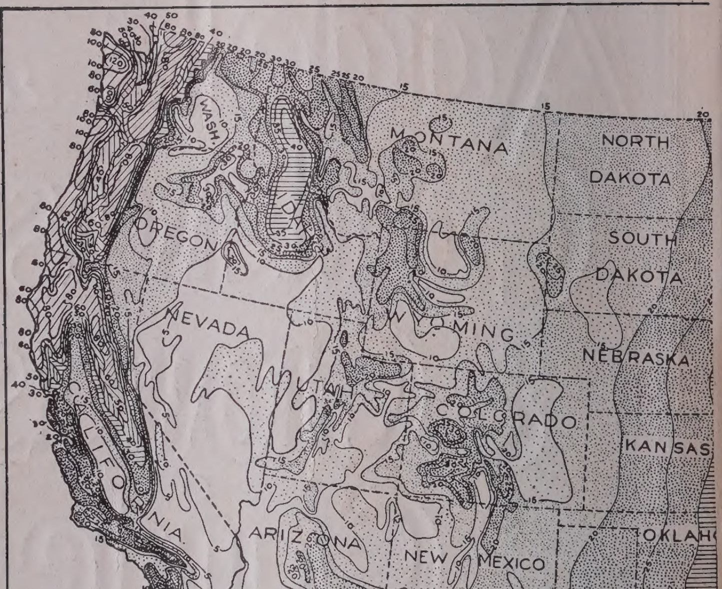
Audels 2

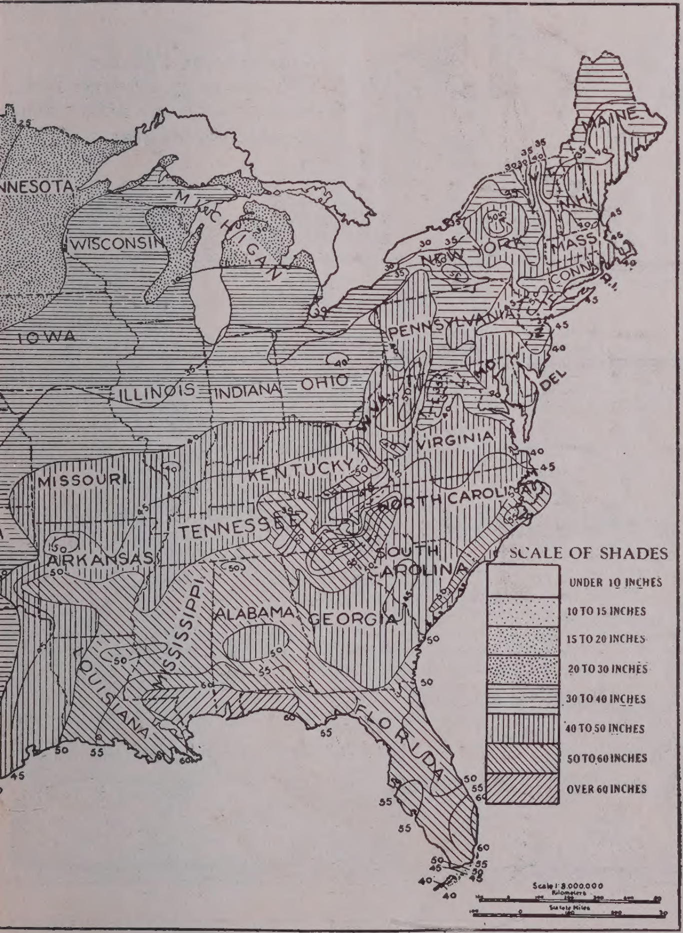
Gardeners & Growers Guide

Working
Fertilizing
Irrigating
Draining
The Soil





Average Annual Precipitation in Inches


NNESOTA
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W.VA.
VIRGINIA
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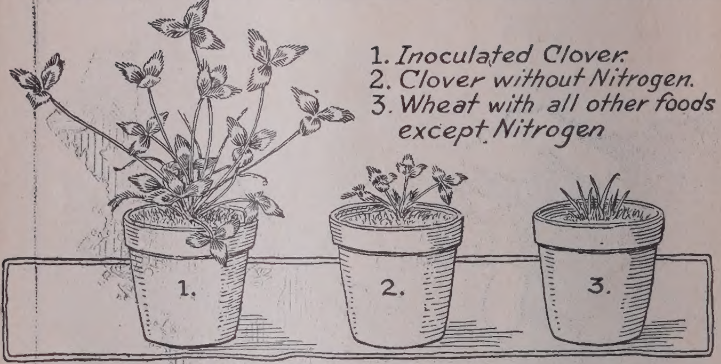
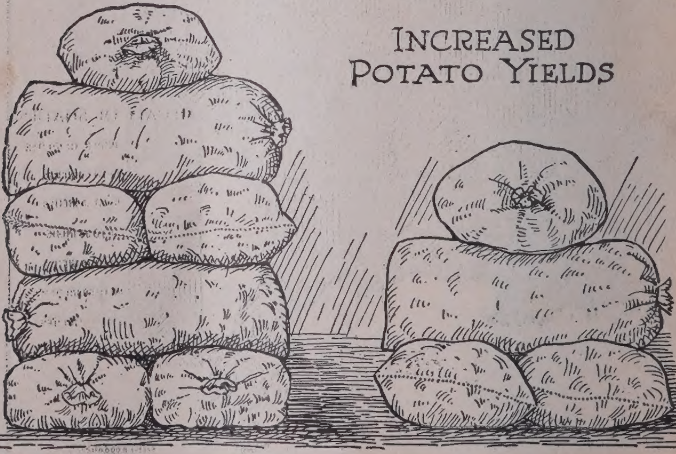
MISSOURI
TENNESSEE
NORTH CAROLINA
SOUTH CAROLINA
ARKANSAS
MISSISSIPPI
ALABAMA
GEORGIA
LOUISIANA
FLORIDA
SCALE OF SHADES
UNDER 10 INCHES
10 TO 15 INCHES
15 TO 20 INCHES
20 TO 30 INCHES
30 TO 40 INCHES
40 TO 50 INCHES
50 TO 60 INCHES
OVER 60 INCHES
Scale 1:8,000,000
Kilometers
Statute Miles



1. *Inoculated Clover.*
2. *Clover without Nitrogen.*
3. *Wheat with all other foods except Nitrogen*



INCREASED POTATO YIELDS

In the abundance of the yield is the joy and glory of the husbandman.

Audels Gardeners and Growers Guide

Volume 1

Presenting in a handy form a wealth of information, instructions and suggestions on

Soil Management

INCLUDING

Irrigating, Draining and Fertilizing

FOR

Good Productive Crops

TOGETHER WITH

Practical and helpful illustrations-Useful and valuable tables of requirements for field and garden

BY

Edward C. Vick

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Foreword—

THIS book explains in simple language and briefly, the basic principles of successful soil cultivation, which every farmer and gardener should understand.

The author here expresses his appreciation of the guidance, education and advice received from his father, James Vick, a distinguished educator in the fields of agriculture and horticulture.

E. C. Vick.

AUDELS GARDENERS & GROWERS GUIDES

FULLY ILLUSTRATED POCKET SIZE

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Giving successful cultural directions for growing each vegetable, arranged alphabetically, and including market gardening.

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GUIDE No. 4—*Beautiful Flowers*

Giving successful directions for the cultivation and propagation of annuals, perennials, dahlias, roses, gladiolas and all other flowers, including shrubs and lawns.

Dedication

Dedicated

To the Encouragement of all Growers

The Author

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Chapter I

THE ORIGIN OF THE SOIL

Countless millions of people have sprung from and returned to the soil of the earth.

In the Old Testament are records of vast armies, unequalled in numbers by any of modern times; of hordes that lived and died through many centuries. Asia has been peopled, for we know not how many thousand years, with masses and Europe has been over-run with humanity for centuries.

On the American continents races of large numbers have lived, for no one knows how long, and disappeared; the last of the natives in North and South America dwindling gradually to comparatively few.

It is impossible to estimate the multitudes that have lived in past ages—and died. In our own times more than 3,500 persons die every day in the United States. In a month of thirty days that is 105,000 persons—1,260,000 in a year.

We know from remains found, that the earth was inhabited by monstrous animals of various kinds, far greater in size than the elephant, also gigantic birds, all of which have passed into the earth and are now extinct.

The people who have lived before, raised flocks and herds. Hundreds of kinds of wild animals have lived, reproduced their kind in numbers. All have returned to earth except those now remaining. Many animals including some within the memory of persons now living have become extinct or nearly so, such as the wild pigeon, which were so numerous as to be troublesome to farmers seventy years or so ago, also the bison which once covered the plains of North America.

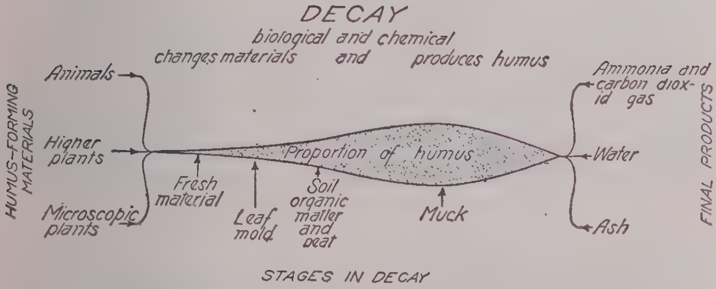
Luxuriant growth of plants, far greater in size than those now found, with the possible exception of the California red wood, as shown by fossil remains, finally covered the dry portion of the globe, or that inundated only to shallow depths.

Taking the animal population as a whole, including human beings, there is a more or less fixed percentage expiring every day. The same is true in the plant world. All going back to earth. Life seems to be sort of a perpetual dying, and resurrection in births, and then the destruction of the living animal and vegetable matter. This process supports the life of the living, including the human race.

It is seen, therefore, that the soil is not only the physical source of all life, but also a result of the life it nurtured. Soil, and life itself, are in a way synonymous. Consequently, it is fitting to approach the study of the soil, and its cultivation, with due regard for the importance, dignity and beauty of the subject.

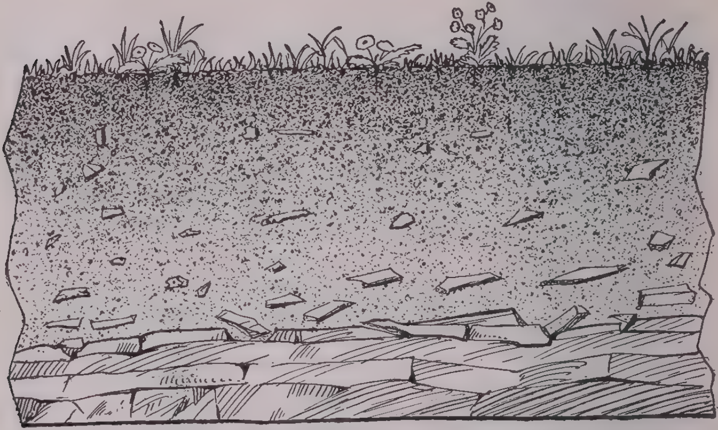
What Soil Is.—Take a handful of good garden soil, place it in a pan and heat it. The moisture will evaporate and the soil will become dry. Continue the heating and it will smoke, finally sending off an odor of something burning. This is organic matter (either vegetable or animal life) or residue, or both. It is this organic matter that makes soil loose and mellow and more retentive of moisture.

Mineral matter does not burn. After the burning process, the matter remaining will be found similar to the particles in sand and sufficiently hard to scratch the polished surface of metal or glass.

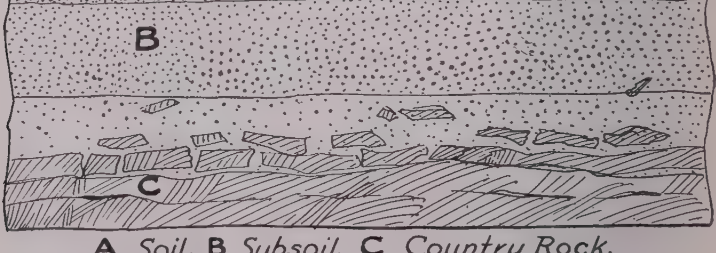


Soil developed from crushed rocks and animal matter

Originally, the dry surface of the earth was all mineral. The soil has been made from rocks, ground up by the action of flowing water; water expanding in freezing and breaking the rocks; monstrous glaciers moving forward with tremendous weight, grinding the rocks to powder; low forms of plants starting in crevices, first the lichens and mosses, followed by larger plants growing in the decayed remains of the others, mixed with particles of crushed rocks. The process continued progressively, great roots still further tearing the rocks asunder. Soft as a mushroom is, it has been known to raise a heavy flag in a stone walk several inches, showing the force of even so tender a plant.



The surface of the earth which was originally all mineral was ground up and developed into soil by various forces

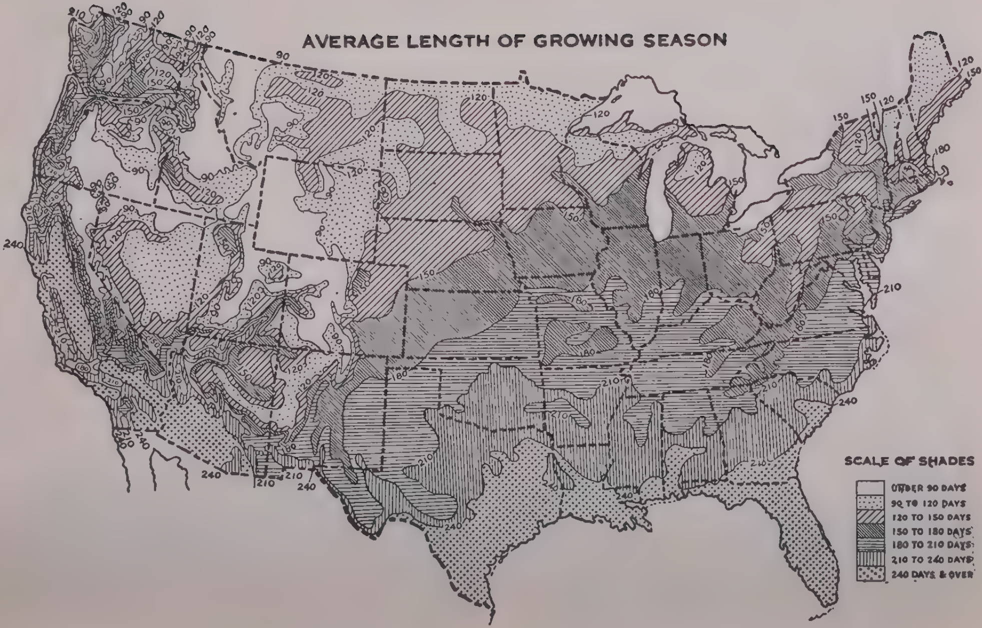


A *Soil.* B *Subsoil.* C *Country Rock.*

The passing of water, gravity, cold and heat played their parts in dividing the surface of the earth into 3 distinct layers: A, Soil; B, Subsoil; C, Country or basic rock

The action of cold and heat played their parts in crumbling the rocks. Finally great trees were felled by the elements and these decaying added greatly to the surface soil. The foliage of trees and plants dropped annually, grasses and other plants grew and died; animal life appeared, died and decayed, the process continuing for ages, as in preparation by a wise Creator for the habitation of man, and animals were provided for his support and comfort.

It is supposed that the first plants that appeared lived wholly or largely immersed in water at a time when the earth was covered with water. Finally, as the land appeared, the plants occupied the land and some scientists are of the opinion that the plants changed their character, abandoning the water for the land. Gradually, the plants obtained more air and direct sunshine, developing from herb to shrub and from shrub to tree.



AVERAGE LENGTH OF GROWING SEASON

This map will prove to be an interesting reference to all growers

Chapter II

THE NATURE OF THE SOIL

To grow crops profitably, good, rich, deep soil is essential. With intelligent labor, almost any soil can be made good. The better the soil to start with, the easier and less expensive it will be to get it into profitable productive condition.

Soil is what we call the top layer of the dry surface of the earth. In thickness, it varies from a thin coating to several feet. Usually, on cultivated lands, the soil extends to the plow line and sometimes deeper. The deeper the soil, the more productive it is likely to be, other conditions being favorable.

Subsoil is the harder earth beneath the surface soil, and this may be sand, clay or gravel. In the humid regions of the East, where there is liberal, frequent rainfall, there is generally a definite line of demarcation between the soil and the subsoil. In the hot and waterless regions of the country, there is little difference between the soil and the subsoil.

Deepening the soil is good practice, but this should be done gradually. If plowing has been six inches deep, go an inch deeper the next plowing and so on each season, until the soil is worked down to a depth of ten or twelve inches or more. Care is necessary in this operation as the productiveness of the topsoil may be greatly reduced by introducing too much subsoil into it at one time.

Soil six inches deep is very shallow; from six to twelve inches is shallow, although in some parts of the East, soil a foot deep is spoken of as "deep soil." And good crops are raised on soil a foot in depth. From twelve to twenty-four inches is deep, but is only considered medium-deep in regions of very deep, rich soil. Twenty-four to thirty-six inches is very deep soil. Under favorable conditions a corn plant will send its roots down three feet into the earth, which shows the desirability of deep soil.

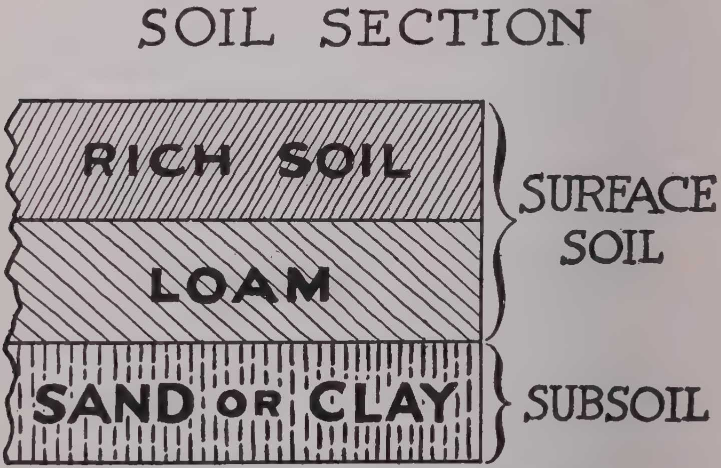


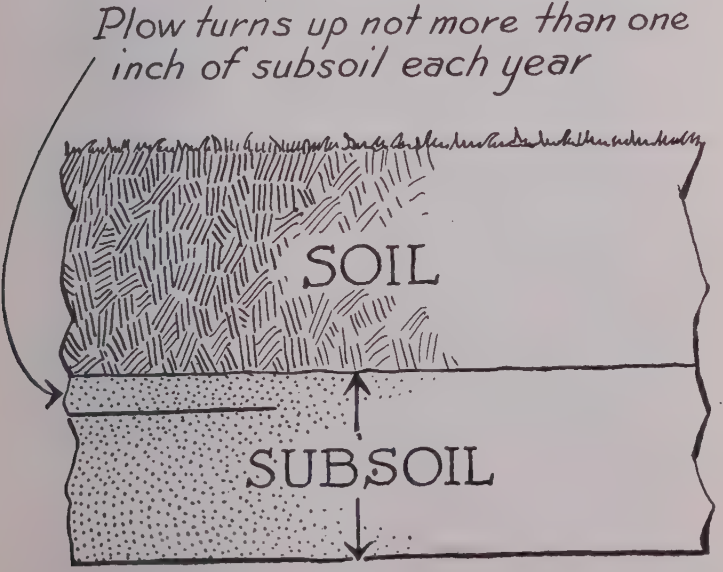
Diagram illustrates a further division of the soil

Good Subsoil.—Retentive power in the subsoil is valuable, as it aids in storing water and prevents the leaching or draining of soluble plant foods.

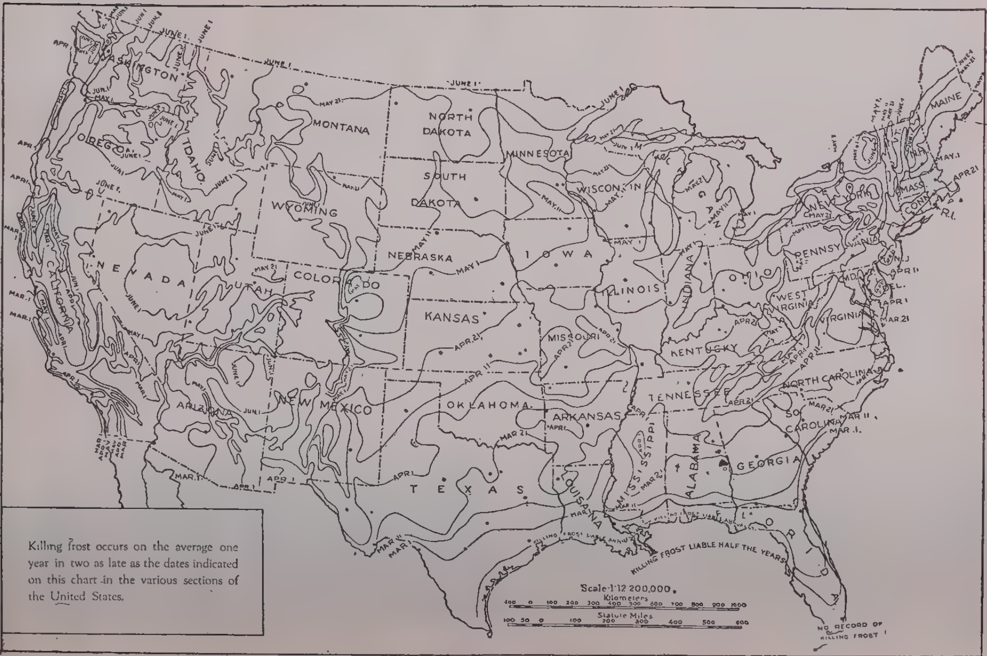
Nonporous subsoil under heavy soil is bad. Porous subsoil under sand is bad. Heavy soil with a porous subsoil, or sand soil with nonporous subsoil are conditions to be desired.

Color of Soil.—The light or dark color of a soil indicates the lack or presence of organic matter. A dark soil, provided drainage and climatic conditions are favorable, is usually a productive soil.

A dark soil absorbs heat faster than a light soil, and other conditions being equal, will mature crops earlier than a light colored soil. A dark red soil will absorb heat almost as rapidly as a soil nearly black. A red or dark blue soil, usually indicates poor drainage. Color alone cannot, however, be depended upon to prove a soil either rich or poor.



Too deep a cut into the subsoil would weaken the quality of the surface soil



Killing frost occurs on the average one year in two as late as the dates indicated on this chart in the various sections of the United States.

Chapter III

THE OBJECT OF TILLING

Few there are who fully realize that the life of the inhabitants of the earth and the perpetuation of the human race depend on the skillful management of the soil. During the World War, it will be remembered that little sugar was obtainable, regardless of price offered. That was as near to a famine as Americans

STRAIGHT WELL TURNED FURROWS
N, Y, State College Agriculture

have approached. But it indicates what could happen if soil cultivation should not be expertly attended to. Food cannot be manufactured; it comes only from the soil and considerable time is required to produce it.

The grower has many things to consider

Tillage is the care of the soil in which crops grow. Its object is to provide proper food, moisture and air for the plant roots and for the soil organisms which help support the plants and to discourage injurious organisms.

The object of the farmer and gardener should be to make the soil, at all times, deep and so full of organic matter as to hold ample moisture; to keep it stirred for aeration during the season when it can be worked; and to keep it neutral or sweet.

All this is necessary so that the beneficial soil organisms may multiply and the plant roots spread rapidly.

Buckwheat—Well prepared, early plowed land.

The accumulation of surplus water should be prevented; the availability of water and plant food determined; the plants properly fed so growth may be vigorous and uniform throughout the field; weeds kept down and erosion or surface washing prevented.

Large tracts are turned with a plow and then disked and the surface fined with a harrow. Small plots such as gardens are usually worked by hand, with a spade or garden fork, as in this manner the work can be done more conveniently and thoroughly.

Tillage implements include plows, harrows or drags, rollers or crushers, and cultivators.

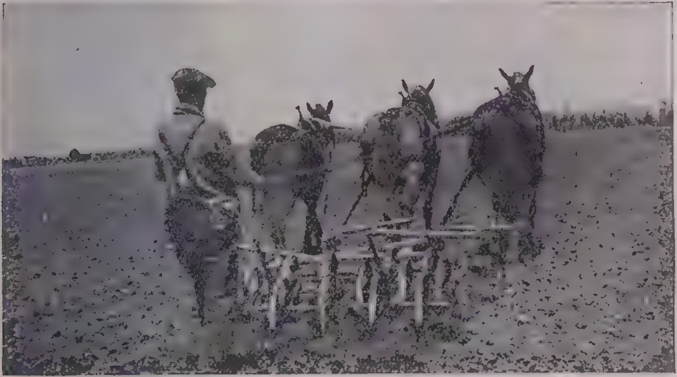
TURNING UNDER GREEN CROP—ALFALFA
U. S. Dep't Agriculture

The plow is for the first preparation—turning over the soil, covering stubble, manure and rubbish.

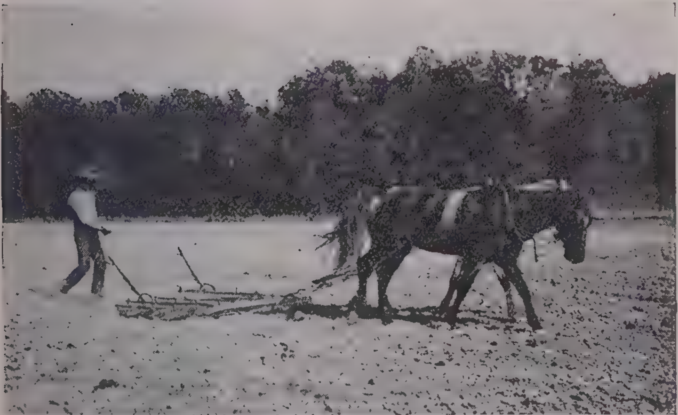
The disk harrow follows the plow, parallel with the furrows, on sod or heavy soils and is sometimes used in place of the plow on light soils. This is followed by the spike tooth harrow.

Cultivators are used to stir the soil between the rows of growing crops, to keep down weeds, preserve the moisture in the soil and increase aeration.

The disk harrow is best for fields filled with roots or rubbish, as it chops these up without clogging the implement.



HOW THE SPRING TOOTH HARROW IS USED
U. S. Dep't Agriculture

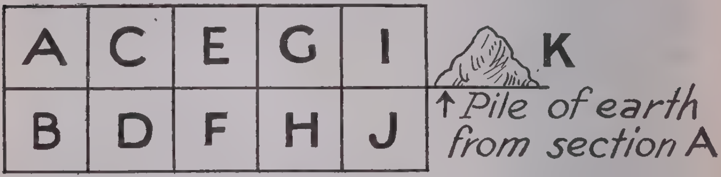


HARROWING PLOWED FIELD WITH SPIKE TOOTH HARROW
U. S. Dep't Agriculture

The spring tooth harrow will fine the soil more deeply, after plowing than the spike-toothed harrow. Where large lumps are brought to the surface, they may be crushed by other means.

The roller is to pulverize lumps and compact the soil. Sod land is rolled after plowing, traveling with the rows, followed by a disk harrow.

Shallow stirring or cultivating prevents disturbing the roots of crops. Deep cultivating wastes water. Frequent and shallow cultivation, before the weeds get deep root is preferable to deeply stirring the soil, after crops have started.



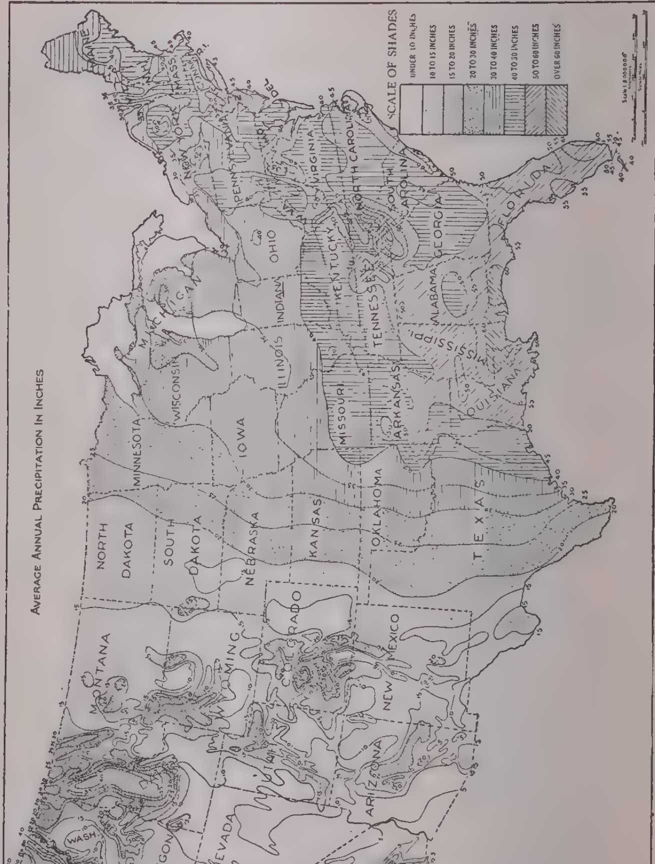
SEE TEXT FOR EXPLANATION OF THIS DIAGRAM

Trenching.—Where exceptionally good results are desired or it is the object to immediately make the soil as deep as possible, trenching is resorted to. This is, however, more common in Europe than in America. The object of trenching is to loosen the soil and enrich it deeply, without bringing the subsoil to the surface. Here is the process:

A trench is dug crosswise of the bed, to the width and depth of the spade, in section A. The topsoil from section A is transported in a wheelbarrow or otherwise, and piled at the other end of the bed, at K. Then manure is thrown in the trench and the bottom section, B, turned over with the spade, working in the manure. This leaves an open trench at A. The topsoil from C is then thrown into the trench A, and section D is treated as was B, and the operation continued until section I is placed in G and J turned, after which the pile of topsoil at K, which was removed from section A, is thrown into I, and the bed is ready for planting.

In turning the top sections A, C, E, G, and I manure is liberally incorporated with the soil.

Wonderful sweet peas and other crops can be grown in this manner.



Average Annual Precipitation In Inches

Chapter IV

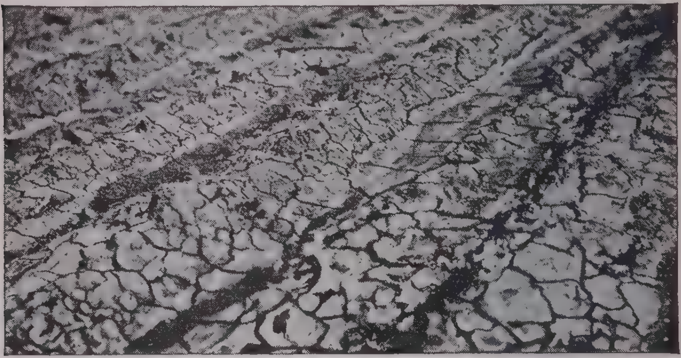
THE KINDS OF SOIL

In considering the effect of various soils on plant growth, it is necessary to know the nature of the soil particles, the amount and distribution of the rainfall, the soil in relation to the land about it and factors affecting its relative temperature and water supply—depth of soil, nature of subsoil and its relation to plant roots, air and water.

Rolling Land.—It is rarely that fields of a considerable rolling character can be maintained at as high a productive capacity as level fields. Water drains quickly from the higher to the lower levels, causing a deficiency on the elevations, washing out or leaching of plant food which may be lost in the drainage. At times this causes an excess of water at lower levels. Washing or erosion of the land is often troublesome on hillside areas.

Clay is finely pulverized soil, made of parts so fine they can only be seen with the aid of a microscope. The particles are 0.0002 inch in diameter. Clay is soft and sticky when wet, has a greasy "feel" and can be moulded into forms. It is hard when dry and is difficult to work when either wet or dry. Clay soils hold water and are cold; they are heavy—that is, closely compact.

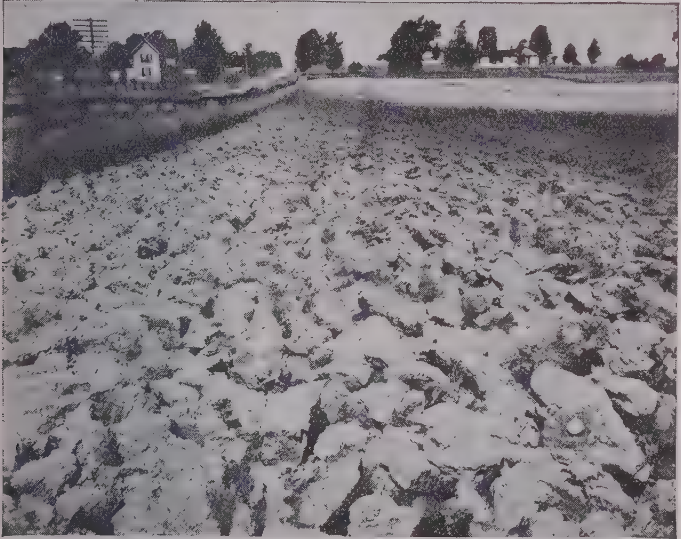
Clay soils can be improved by draining with ditches or tile drains. They can also be improved by working into them large quantities of organic matter such as stable manure; or by growing green crops such as rye, clover or other crops and turning them under. The liberal use of lime or pulverized limestone is also beneficial on clay. Sodium nitrate, called nitrate of soda, on heavy clay soils causes deflocculation, making the clay stickier or more adhesive, causing it to shrink more in drying and leaving large cracks at the surface. This should be considered in using nitrate of soda, as a fertilizer on clay soil.



BAD SOIL CONDITION THAT CAN BE QUICKLY IMPROVED

Clay soil in small gardens can be quickly improved by spreading evenly over the surface, two or three inches of range or furnace ashes. Ashes from a power steam boiler are not suitable. Or, sand may be used in place of ashes. After the ashes, or sand, have been evenly spread, turn them under. Break up the soil as completely as possible in the operation and mix the ashes or sand thoroughly with it. Then spread manure or decayed leaves over the surface and in like manner, turn these under.

Very stiff clays may require this treatment a second season until the hardest clay is made soft and friable.

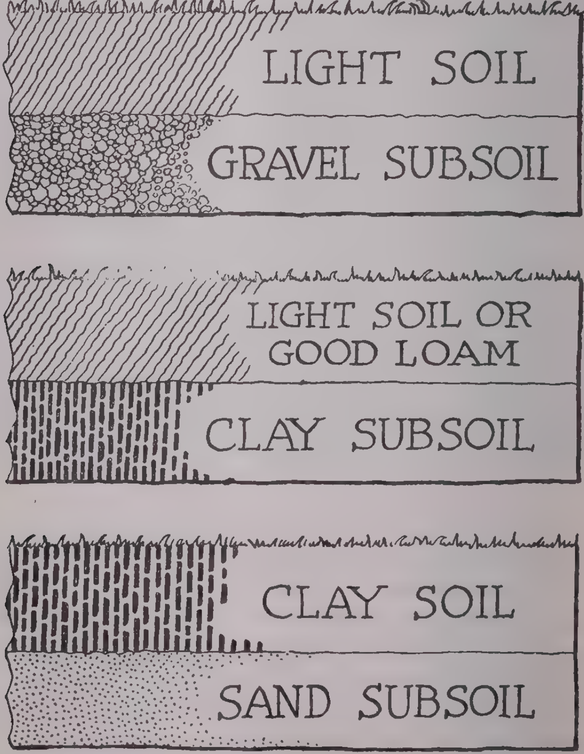


BADLY DRAINED AND POORLY TREATED CLAY SOIL
Courtesy U. S. Dep't Agriculture

Loam is a mixture of clay and sand. A clay loam has more clay than sand and a sandy loam contains more sand than clay. Loam is granular and porous; moisture passes through readily; fertilizers are retained and plant roots thrive in it.

Sandy soil is known by its grain and by its gritty feeling when rubbed in the hand. The particles can readily be distinguished. It is loose, open and porous and does not adhere when compacted. It is light and warm and the drainage is good. Sand is any rock fragment between 0.5 and 0.05 mm. in diameter. Sandy soil is improved by liberally adding organic matter.

Sandy soil, when well fertilized, has many advantages over cold, poorly aerated clay soils. Clay soils are more difficult to drain and work. This is particularly true when irrigation is to be practiced.



GOOD COMBINATIONS OF SOIL AND SUBSOIL
Clay is satisfactory soil when in combination with other lighter soil

Sandy soils are inclined to yield early crops of high quality rather than heavy crops. The tendency of sandy soil to drought, except where the water table is high or near the surface, induces early maturation and sowing can be done early in the season, before heavy soil can be worked. Market garden produce, fruit and nursery stocks are often raised on sandy soils.

Organic manures are necessary to increase the water holding capacity of sandy soils. Frequent green manuring and cover crops are essential. Ground limestone and Kainit are profitable to use on sandy soils and nitrates often give remarkable results. Phosphates are not usually required. A careful test should be made before adopting any costly plan of fertilizing sandy soils.

Silt is composed of particles in size between sand and clay.

Gravel is small, more or less rounded stones and pebbles. Gravel is suitable for growing some tree fruits and vines, such as grapes.

Peat is composed almost wholly of partially decayed vegetable matter. It is formed in swamps, on the edges of lakes or ponds, where the plants spring into growth every year and die down, the process continuing for years, eventually forming a deep bed, in some cases completely filling the depression which formed the lake or pond. When thoroughly dried, peat makes excellent material for lightening heavy soil.

Muck is peat in a more advanced stage of decomposition. When properly drained and cultivated, it grows good crops of celery, lettuce, onions, potatoes, radishes and some other crops.

Weight of Soils.—Fine sandy soils are in reality the heaviest in weight, although they are called light soils. Peat soils are the lightest when dry. Saturated with water, however, a cubic foot of peat soil weighs more than a cubic foot of sand.

The weight in pounds of soils, per cubic foot, is approximately as follows:

Fine sandy soil, 1 cu. ft. weighs in pounds	**95 to 110**
Loam soil, 1 cu. ft. weighs in pounds	**75 to 90**
Clay soil, 1 cu. ft. weighs in pounds	**70 to 75**
Peaty soil, 1 cu. ft. weighs in pounds	**25 to 40**
Prairie soil, 1 cu. ft. weighs in pounds	**75**

Soil Particles.—It has been estimated that a gram, or about one-half ounce, of productive soil contains from 2,000,000,000 to 20,000,000,000 soil particles; soils that contain less than 1,700,000,000 soil particles are unproductive.

The number of particles per gram of different types of soil is approximately as follows:

Early truck	1,955,000,000
Truck and small fruit	3,955,000,000
Tobacco	6,786,000,000
Wheat	10,228,000,000
Grass and wheat	14,735,000,000
Limestone	19,638,000,000

If the particles are all spheres in a cubic foot of soil, a surface area of from two to three and a half acres is available to contact the plant roots, in this one cubic foot!

Alkali Soil.—Soils containing sufficient alkaline salts to be destructive to vegetation (such as sodium sulphate, sodium or potassium carbonate or chloride), found in semi-arid regions, are called alkaline soils. Alkaline compounds coat the surface, when evaporation takes place. Sodium carbonate dissolves the humus and forms a black solution which causes black alkali.

Some soils supposed to be alkali, on account of their white coating, are in reality limestone soils.

When alkali land is to be cultivated, the alkaline content should be determined by chemical analysis. Sometimes good drainage and proper irrigation is all that is required to improve it. Irrigation without drainage may make the condition worse. Deep plowing should be practiced and a few loads of good soil from a fertile field added, to encourage nitrification. Oats are the safest crop for the first seeding.

Residual Soils are soils formed where they are. That is to say, they have not been transported by any means.

Cumulose Soils consist of soils that have accumulated in basins. This soil accumulates from plants growing and finally falling down to be covered by the water in which they were growing, eventually forming beds of peat or muck.

Colluvial Soils are made up of fragments of rocks, detached from the heights above, in hills or mountains and carried down the slopes by gravity to the valleys below.

Alluvial Soils are soils that are transported or have settled down, after being carried by water, or soils deposited by streams that sometimes overflow their banks. In valleys, colluvial deposits sometimes mingle with alluvial deposits.

Marine Soils consist of soils that are constantly being carried away by rivers into the sea. They usually consist of stratified gravels, clays and sand subsequently raised above the sea, due to a change in land elevation. Marine soils are quite widely distributed in the Eastern states.

Glacial Soils are usually composed mostly of clay loams or silt loams. The prevailing colors are gray, brown or black and sometimes blue clay. The hill soils of central New York are largely glacial formation.

Lacustine Soils vary widely in character and are spoken of as glacial lake soils. They are formed in lakes by the action of glaciers. Found in New England, westward along the Great Lakes to the Red River valley.

Aeolian Soils are fine soils that have been distributed by the wind over large areas, as in the Mississippi, Missouri and Ohio valleys; also in Arizona and New Mexico, in which states it is called adobe. Sand dunes are Aeolian soil.

Adobe Soils are fine calcareous clay or silt and when irrigated are very fertile.

Loess Soils are usually a fine calcareous silt or clay, deposited by the action of the wind. These soils are high in lime and phosphoric acid content and cover large areas in the central United States. Where moisture conditions are favorable, loess is a very fertile soil.

Calcareous Soils are soils where calcium carbonate content exceeds average content by about ten per cent, becoming the controlling factor in the soil's properties. The fact that calcareous rock abounds is not proof that the soil itself is calcareous.

Chapter V

SOIL LIFE

A moist, rich soil contains many classes of micro-organisms. Their precise relation to the growing plant has not been determined. Some are valuable and important as they are conducive to the production of plant nutrients. Some are harmful to plants.

Injurious soil bacteria and fungi cause trouble by attacking the roots of plants causing knots on the roots of cucumbers, tomatoes and other plants. Others attack other parts of the plants, but may live in the soil during their spore stage. Wilt of watermelons, cowpeas, tomatoes and other plants are some of the results. The damping off of seedlings or cuttings are caused by soil organisms and so are galls. Infected soil usually remains so for a long time.

Some organisms in the soil cause diseases in human beings, such as typhoid fever. These sometimes find their way through drain water into wells, causing the spread of the disease directly through the drinking water, or indirectly through it in cow's milk.

Among these invisible soil organisms are yeasts, protozoa, fungi and bacteria. As many as 30,000,000 have been found in a gram of rich soil.

Not all the experiments of investigators of soil organisms up to the present time can be considered final. The results in some cases may have been deceiving and later will be controverted. Much remains to be learned by soil chemists and botanists regarding the soil and its relation to growing crops.

Sufficient is known, however, to prove that unless the soil abounds with unseen plant life, it will not produce crops.

Leguminous plants, such as peas and clovers, possess nodules on their roots which contain numbers of bacteroids. The organism, which has been named **Bacillus radicicola,** enters the plant roots at an early stage, and having brought about the formation of the nodule, manufactures nitrogen compounds for the plant, from the nitrogen of the air.

Some trees and shrubs, including beech and heather, become associated with fungi which grow on their roots and aid in their nutrition.

Some bacteria cause changes which make the elements in the soil available for plant food. The vegetable, animal and organic matter in the soil are decayed by the action of the bacteria and not until then can the soil be utilized as food by the growing crops.

Bacteria abound in manure piles as well as in the soil. They need no light, but require air, moisture, warmth and food. Helping the favorable bacteria to thrive, helps to keep the unfavorable under control.

Simplification of soil population in some cases may lead to increased productiveness, as shown by recent experiments in partial soil sterilization by the use of steam. On the other hand, conditions which have been favorable to life in the soil, warmth, moisture and organic manures, used in greenhouses, lead to reduced productiveness of crops after a time. Apparently the detrimental organisms increase too rapidly under these conditions and affect the growing vegetable or flowering plants.

Good Soil must contain, not only food for the plants, but moisture and air for both bacteria and plant roots, and be sufficiently soft to permit the tender, thread-like roots to penetrate. The vigorous development of plants above ground depends upon the flourishing root development in the soil.

Too much manure may result in denitrification. Market gardeners who use manure very heavily, at the rate of forty tons to the acre, sometimes have this trouble. Heavy and continued green manuring may produce the same result. This is corrected by permitting the organic matter to partly decompose, before adding chemical fertilizer.

Fungi and bacteria cannot live without oxygen, nor can the roots of plants. Seeds will not germinate without it. The more air there is in the soil, the more fertile will it be. Rainwater sinking into the earth carries air with it.

Where rainfall is insufficent, there may be too much air in the soil. In dry regions the effort should be to increase the moisture-holding capacity of the soil, without making it so light as to dry out. Compressing by rolling and packing, rather than deep stirring, is needed in such cases.

Organic matter increases the volume of air in the soil, which in humid regions is beneficial. In arid sections it may be injurious unless the soil is supplied with sufficient water to keep the soil damp. The organic matter might otherwise make the soil so open as to cut off all capillary attraction, and the surface would become completely dried out, resulting in the loss of whatever was planted on it.

About ten per cent of the volume of normally moist soil is occupied by air, but this constantly varies inversely as the amount of water varies.

Where Aeration is Needed.—From the western end of the Corn Belt, throughout the East, also in all humid sections and on all irrigated lands, the soil needs ample aeration through cultivation, drainage, rotation of crops and manuring. Plowing, harrowing and cultivating are the necessary operations, and manuring to increase the organic content of the soil.

Want of Air Causes Loss of Nitrogen.—The bacteria in moist soils, requiring oxygen are largely, but not entirely, dependent upon air for their oxygen supply. In the absence of air-oxygen, they have the power to destroy certain chemical compounds for the oxygen these compounds render. According to Prof. Joseph A. Jeffery, the nitrates are among the compounds they destroy.

When air is excluded from a soil containing nitrates, the bacteria attack the nitrates and remove the oxygen from them and thus render the nitrogen of the nitrates useless for the crops and the rate of destruction may be rapid. Sufficient nitrate has been destroyed in two weeks to produce a crop of wheat. This is denitrification and the bacteria are called denitrifiers.

Chapter VI

SOIL STRUCTURE

The structural condition of the soil is a point to be carefuly studied. It is the structure of the soil that determines the circulation of air and water. In improving soil conditions structural and physical changes are just as important as chemical changes.

Soil Structure refers to the arrangement of soil particles. The structure may be loose or compact, friable or hard, or granulated.

Soil Texture refers to the size of the soil particles and the number of the particles in the soil. Soil texture cannot be very greatly changed.

Good Mechanical Condition of Soil.—When soil that is moist will crumble when compressed in the hand and becomes loose when tilled, it is in good mechanical condition for growing crops.

Physical Condition of Soil relates to its organic, mineral and moisture content.

Plasticity is the sticky condition of soils when wet. The finer the soil texture or particles the greater the plasticity. Clays with the finest texture have the greatest degree of plasticity. A plastic soil, moulded into shape when wet, will retain that shape when dry. Sand may be somewhat plastic when wet, but when dry, it falls apart.

Plastic soils exhibit a certain amount of expansion in wetting and shrinkage upon drying. The checking of clay soil when dry is an illustration. As the soil dries the film of water at the surface is gradually reduced about the soil particles, which move closer together as the water evaporates and the cracks are the result of the shrinkage. As the cracks open, evaporation is hastened and their depth increased.

Where large cracks occur, the roots of plants may be broken or injured.

Remedies required in such soils are:—**First,** reduction of soil moisture by proper drainage; **second,** the addition of a binding material found in lime; **third,** liberal addition of organic matter, and **fourth,** tillage.

The more plastic the soil is, the more likely it is to become puddled by tilling, particularly if it is not well drained.

Puddled Soil is soil in which the particles fit so closely together as to leave practically no pore space between the soil particles. It prevents root development, also the circulation of air, and is almost impervious to water.

A clay soil should not be plowed or worked while wet as the soil particles would then be worked into a puddled condition and become very hard when dry. Such soil should not be plowed until it will turn over and granulate well. Some sandy soils may be plowed or cultivated immediately following a hard rain.

Improving Plastic Soil.—Plastic soil is usually cohesive, its particles stick together in an intact mass. Soils of this character are improved by making them more granular and friable by good drainage, a liberal supply of organic matter and liberal application of lime or ground limestone.

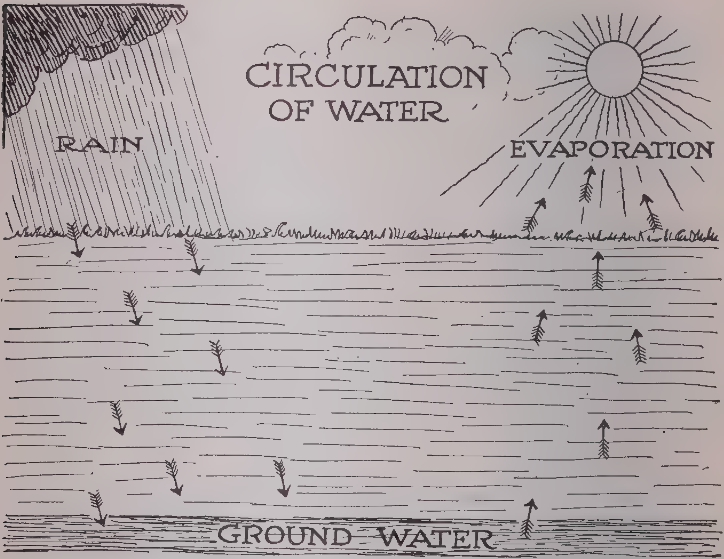
Improving Sandy Soil.—Sandy soils will be made more plastic and cohesive by the liberal addition of organic matter and lime in small quantities.

Organic Matter in the soil's structure is commonly called humus. Technically, humus is not a definite single substance but an indefinite and complex mixture. As stated elsewhere, organic matter is composed of either vegetable or animal matter or both. It increases the water holding capacity of the soil, stores up the energy of the sun, nourishes the growing plant, liberates energy for and nourishes micro-organisms. Comparatively little is known at present of the entire function of the organic matter of the soil. Scientists are learning more about it, but the difficulties encountered in the work are almost insurmountable.

Organic matter slowly disappears from the soil and the supply should be kept up and increased.

Leaves that fall from trees in autumn are a valuable source of organic matter. This precious material is frequently permitted to go to waste and is often destroyed by burning. Not much attention was formerly paid to the importance of using leaves as a fertilizer until manure became scarce. The importance and value of saving and storing leaves is now generally acknowledged.

In France, Belgium and Germany, for example, the removal of leaves from the forests, by farmers who appreciated their value and applied them to their lands, has led to such bad effects in the state forests, that the practice is now forbidden.



HOW WATER CIRCULATES AND NOURISHES PLANTS
Plants transpire from 200 to 500 pounds of water to each pound of plant

Chapter VII

WATER IN THE SOIL

Different substances in the soil are required for plant growth, but only such as dissolve in water in the soil, can be taken up by the plant roots, passing into the plant to be utilized for its growth.

Importance of Water.—Growing plants are composed largely of water. From sixty to more than ninety per cent of the green weight of staple crops is water. Most of this water is taken from the soil and contains the food which passes up to the leaves where it is digested, the surplus water being passed off into the atmosphere. The evaporation of water from the leaves of trees is one reason why the air in a piece of woods is considerably cooler than that surrounding it. Trees about the house, in addition to the cooling shade, reduce the temperature by the moisture that transpires through the foliage.

On hard land rain runs off or is held on the surface. It is important to have the soil soft, so the rain water can sink in and be held there for use by the plants between rains. In dry time, the water that has sunk in, is drawn up by capillary attraction, as the oil in a lamp is drawn up through the wick, to the flame.

Plants transpire from two hundred to five hundred pounds of water for each pound of dry matter, in the humid regions and double that in arid regions.

Table of the amounts of water (by Prof. F. H. King) in tons, per ton of dry matter and in inches of water per ton, lost through transpiration through the plant and evaporation.

Evaporation Table

	Tons of Water													
Dent Corn	used	309.8,	equal	to	2.64	in.	of	water	per	1	ton	of	dry	matter
Flint "	"	233.9,	"	"	2.14	"	"	"	"	1	"	"	"	"
Red Clover	"	452.8,	"	"	4.03	"	"	"	"	1	"	"	"	"
Barley	"	392.9,	"	"	3.43	"	"	"	"	1	"	"	"	"
Oats	"	522.4,	"	"	4.76	"	"	"	"	1	"	"	"	"
Field Peas	"	477.4,	"	"	4.21	"	"	"	"	1	"	"	"	"
Potatoes	"	422.7,	"	"	3.73	"	"	"	"	1	"	"	"	"

Experiments in Prussia showed the amounts of water withdrawn from the soil and released in the air, almost wholly through the plant, **per pound of dry matter produced,** to be as follows:

Barley	310 lbs.
Rye	353 "
Oats	376 "
Wheat	338 "
Beans	282 "
Peas	273 "
Clover	310 "
Buckwheat	352 "

The Richer the Soil the Lower the Transpiration Ratio.— Other experiments show that in producing a forty-bushel crop of wheat to the acre, the plants will use about six hundred tons of water, not including what escapes from the soil by evaporation, so it is plain to see the necessity of an ample and constant supply of water.

Increasing the fertility of the soil by drainage, green or barnyard manures, fertilizers, lime and good tillage will give a greater amount of plant production for the quantity of water utilized.

It is interesting to know that an inch of water covering an acre of land weighs about 226,875 pounds or more than 113 tons.

Humid Region.—There is no well defined humid region. In the northern portions of the country, where the annual rainfall (precipitation) is as much as fifteen inches a year, we find this is about the western limit of the humid or reasonably successful farming regions. This takes in the Dakotas as the general western limit. Farther south, on account of more sunshine, increased heat, higher wind velocity, etc., twenty inches of annual rainfall will represent the humid limit.

Much of the Pacific Coast is humid, although portions of California, Washington and Oregon are arid, while some localities in the so-called arid regions are humid.

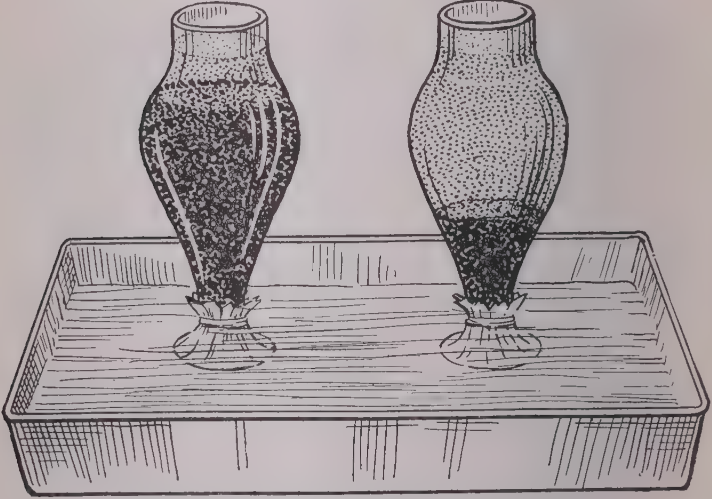
Hygroscopic Moisture is moisture that a dry soil can absorb from a moist atmosphere.

Capillary Water is water held by capillary or surface forces which, being stronger than gravity, prevent water from being lost by drainage. This is referred to again under Gravity Water.

Hydrostatic Water is the standing water that maintains a given level below the surface, depending on the quantity of water in the soil. It is commonly referred to as the water level.

Movement of Soil Water.—Water in the soil moves about from place to place as the result of the attraction of gravity which draws the water down and also capillary attraction that causes water to move in any direction from one part of the soil to another.

CAPILLARY ATTRACTION



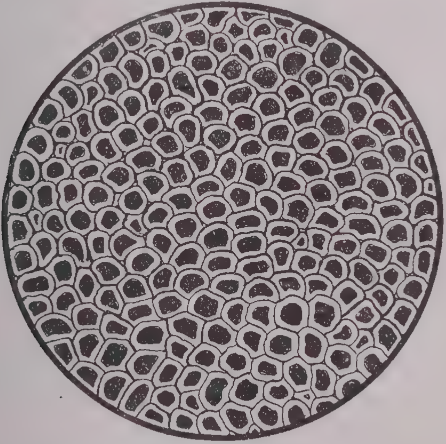
CAPILLARY ATTRACTION ILLUSTRATED

Fill a lamp chimney with fine, dry soil. Tie a cloth over the small end and place in a shallow pan. The water will gradually rise by capillary attraction. Using several chimneys with different soils, it will be seen that the water rises faster in some than in others

Gravity Water.—Water that drains away in the soil is known as gravity water. As the water drains away, each soil grain is surrounded by a film of water, called film or capillary water and the roots of plants make use of the moisture held in this way. The soil retains, by absorption and surface attraction, from ten to twenty per cent of its weight of water.

Soils which present the largest aggregate surface area of the soil particles will likely retain the most moisture per cubic foot.

Prof. F. H. King illustrates the matter as follows: A cubic foot of marbles, each one inch in diameter, has an aggregate surface of 37.7 square feet, but, if the marbles were reduced in diameter to one-thousandth of an inch, the total area per cubic foot would be increased to 37,700 square feet. It will be understood from this that fine grained soils retain much more water than coarse grained soils.



MAGNIFIED SOIL PARTICLES
Surrounded by film of water, illustrating how the finest soil retains the most moisture

The amount of water a soil may hold will vary, not only with the size of the soil particles, but also with the distance of the water-table or level of standing water below the surface, and the frequency of rains.

Where the water table is high and not so high as to interfere with plant growth, say five feet below the surface, a **fine sandy loam** will be moist under the surface, through long seasons of drought.

In New Jersey, some of the sandy soils along the coast produce fine crops when seasons are so dry that production is greatly reduced in surrounding, non-sandy soils.

A considerable amount of soil moisture is unused by crops. Thirty per cent and more likely fifty per cent must evaporate and drain away, before there will be sufficient air in the soil to permit root growth.

Soils like sand, having a small water capacity, yield water more readily to plants than heavier soils and thus the difference in capacity, so far as absorption by the plants is concerned, may be nearly equalized.

Prof. Buckingham found that loose clay contained twenty-six per cent of moisture at a height of forty inches above the water level and compact clay twelve per cent. Loose sand loam at the same height contained six per cent moisture, and compact sandy loam, ten per cent.

Sandy loam soil, although lower in percentage of water, owing to the fact that it releases water more rapidly for the use of plants, produces better growing results than clay.

If water stands for a considerable time on the land, it shuts off the soil air supply and kills the plants and the beneficial bacteria. Lands that do not naturally drain the excess water must be drained artificially, before they can be depended on to grow good crops.

A slight inclination of the land will give drainage. When the inclination is as much as five degrees, the field should be worked at right angles to the incline, to prevent excessive washing. Steep hills are best used for fruit trees along the higher parts, or for pastures, woodlands or vineyards.

Where tile drains are used, these should be placed about three feet below the surface. Open ditches will remove excess surface water and in some cases be all the drainage necessary. More will be told about drainage in a section devoted to that subject.

Lay of the Land.—In addition to giving good drainage, land with a southern slope receives the sun's rays longer and at a better angle than level land or that sloping to the north.

In valleys and low situations, the soil cools more rapidly than on high ground and crops in valleys may be injured by late spring and early autumn frosts, while those on higher land escape. Thoroughly cultivated land is warmer than rough land, as it absorbs and holds more heat. Manure or other organic matter decaying in the soil, produces as much heat by the time it is thoroughly decayed, as though it had been burned.

HONEY LOCUST WINDBREAK. HALL CO. NEB.
PHOTO BY U.S. FOREST SERVICE

WINDBREAK OF TREES CHECKS WATER LOSS

Chapter VIII

HOW TO RETAIN SOIL MOISTURE

Autumn Plowing and Cover Crops.—Land plowed in the autumn will retain more moisture than that left unplowed.

To prevent erosion, loss of plant food, to improve the physical character of the soil and to add humus-forming material, it is desirable to cover the land with a catch crop.

Of the legumes, soy beans, cow peas and crimson clover are used in the southern and central states, also vetch in the south and in the northern states.

Of the non-legumes, rye, wheat, oats, barley, rape, buckwheat and turnips are used generally on land plowed early in the autumn.

Even though freezing weather kills the crop the autumn cover-crop will serve a beneficial purpose.

In the early spring, re-plow, crosswise, if the land is sufficiently level. The double working aerates and pulverizes the soil, improving the physical condition sufficiently to pay for the extra labor. This is the experience of some of the most successful American operators.

In sections where the soil is light or plows badly, autumn plowing may be impractical, unless done sufficiently early so the catch crop can make a fairly good growth.

Some soils in arid climates may be over-mellow and require plowing a considerable time before they are planted, in the autumn, for example, when the planting is to be done the following spring. On soils of this kind, or very sandy soils, the disk cultivator is used in place of the plow, where planting is to follow quickly.

Where the seed bed is loose in the spring, it may be advisable to roll the land. This compacts the soil and establishes capillary action with the earth below, thus the moisture is kept from coming up, keeping the surface soil moist, enabling seed to germinate quickly.

Mulch.—As soon as the seedlings are up, a mulch should be established by cultivating, to check the soil moisture from evaporating.

The so-called soil-mulch keeps down weeds and conserves the moisture and fertility they would otherwise consume. It aerates the soil and increases the water holding capacity.

In dry farming sections, a soil mulch should be maintained throughout the year. Where irrigation is practiced, mulching will make irrigation necessary less frequently, thus saving the cost of water.

Soil mulches must be stirred frequently as they do not long remain effective, particularly early in the season when the earth is damp and the moisture works up from below and breaks down the mulch. There is an old saying that "frequently stirring the soil is as good as manure."

When the ground is covered with growing crops, the land is shaded from the drying power of the sun and protected from drying winds, thus affording their own mulch, to an extent. On this account, close pasturing is injurious—that is, permitting grazing to an extent that takes the grass off close to the earth.

Shelters, or Wind Breaks, of tall growing shrubs or trees, fences or buildings, check the loss of water evaporation by

shutting off the wind, making the land much earlier than when left exposed.

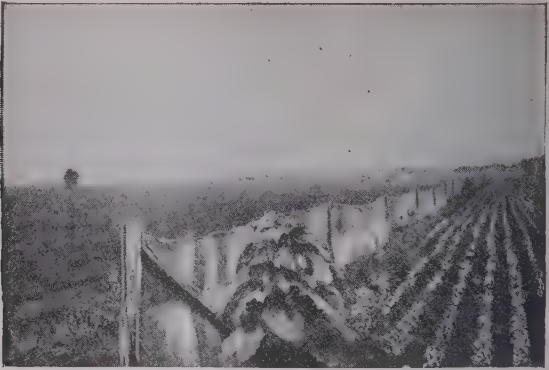
A shelter of trees or shrubs takes moisture from the soil for some distance from the row, but generally is beneficial.

Cultivate Promptly After Plowing.—Soil moisture will be held and evaporation checked, by light cultivation, about three inches deep, as soon as the land is plowed, after disking or harrowing.

Light cultivation as soon as it is possible to work the land after a rain is good practice, as it is immediately after a rain, when the land is wet, that evaporation is greatest.

Some crops, like corn, having roots close to the surface, will be injured by other than the shallowest possible cultivation.

The use of straw, as between the rows of strawberries, may be used as a mulch for holding moisture. Stable manure is excellent and decayed leaves are useful for this purpose. Where a mulch of this kind is used, cultivation will be required only occasionally.



BURLAP WINDBREAKS MAY BE A GOOD INVESTMENT

Action of Plant Roots and Earthworms.—The action of plant roots causes changes in the soil structure by forcing the particles apart. Fine rooted plants, such as grass and wheat, are beneficial to tilth, aiding granulation. The organic matter left in the soil by the decaying roots is beneficial. Grass protects the soil surface. Alfalfa roots work deeply into the soil sometimes reaching a depth of six feet, and in addition to gathering nitrogen, loosen up the soil to a considerable depth, the roots adding organic matter.

Frequent rotation should be practiced on clay soils, so that constant plowing and the root action of different plants will get the land in good condition.

Earthworms and burrowing creatures help improve the condition of the soil. Darwin estimates that the quantity of soil passed through earth worms, in good soil, in a humid climate, amounted to ten tons per acre annually and that from one-tenth to two-tenths of an inch of soil is yearly brought to the surface, in land where earthworms exist in normal numbers.

Chapter IX

PLANT FOOD IN SOIL

Nothing Is Lost in Nature.—All materials are returned to their source eventually. Animals, including man, vegetables and minerals are from the earth and find their way back finally to their source, providing plant food for new living plants.

Tillage is necessary to get the soil in condition for plants, so they can utilize and thrive on the plant food in the soil. The plants, if edible, are consumed by man or animals, their character changed and a portion returned to the earth in the form of manure. The balance reaches the earth again when the animal dies and is buried. Metals oxidize, or as commonly stated, rust or corrode, or wear away and fall back to the earth.

Before the matter returned to the soil can be utilized by plants, the work of bacteria is necessary, as previously explained, changing its condition, so it may be used again as plant food.

Were it not for bacteria and fungi, the soil would soon become foul and unfit to support plant life.

Oxidation in the soil, resulting from air and water, plays its part in disposing of organic matter. Decaying material produces carbon dioxide and other products, which are solvents of mineral matter, aiding in producing nitrogen for the growing plants.

When crops are grown without returning plant food, the soil becomes unproductive.

Crops called legumes, including clovers, vetches, peas and beans, leave the soil in a fertile condition, especially when the crop is plowed under.

A kind of bacteria which produces nitrates in the soil is called collectively, nitrobacteria, and these produce root nodules, storing up in these nodules the nitrogen drawn from the air. Four-fifths of the atmosphere, by volume, is nitrogen, and the leguminous plants, assisted by the nitrobacteria, fix in the soil, on the plant roots, the nitrogen which is drawn in from the air.

Even though the legume crop is harvested, the soil is benefited from the nodules on the roots that are left in the ground. Crops like crimson clover, red clover or alfalfa may acquire from the air, within a single growing season, as much as two hundred to three hundred pounds of nitrogen per acre.

Inoculating Legumes.—In soil where any of the legume crops are to be grown for the first time, it is advisable, either to inoculate the seed before sowing, with cultures sold by seedsmen for this purpose, or may be obtained at some state experiment stations; or to spread on the land, soil from a field where a good crop of the same kind of a legume has been grown. Treating the seed prevents the danger of bringing in troublesome weed seeds or plant diseases which may occur where soil inoculation is used.

Bacteria from one species of legume are not adapted to produce nodules on other species of legumes, so in inoculating soil for alfalfa, bacteria from an alfalfa field should be used and from a cowpea field for cowpeas and so on.

Chapter X

THE ELEMENTS

The earth and the atmosphere are composed of elementary, indivisible substances and combinations of these elements. Eighty-three elements have been recognized and classified by chemists. Symbols are used for convenience in expressing the combinations into which they unite. A table of the elements and their symbols will be useful in order to understand the meaning of symbols in scientific reading on agricultural subjects.

A figure is used after a symbol, when more than one part or atom, by atomic weight, enters into the makeup of the molecule or unit of matter. Water is represented as H_2O, indicating a compound in which the molecules are two parts hydrogen and one part oxygen.

Most of the elements are very rare and most of them are naturally present in combination with others. Oxygen, hydrogen and nitrogen and some of the rarer elements exist in the atmosphere in a free state and also in combinations in the earth, in plants and animals.

Approximately, 99 per cent of the earth's surface, land and water, is made up of ten elements—oxygen, silicon, aluminum, iron, calcium, sodium, magnesium, potassium, hydrogen and carbon.

The atmosphere is a mixture, by volume, of about seventy-nine parts of nitrogen and twenty-one parts oxygen, with small quantities of carbon dioxide, ammonia, argon, water vapor and other gases in addition.

The composition of the human body varies, but is about as follows:

Oxygen	72.0
Carbon	13.5
Hydrogen	9.1
Calcium	1.3
Phosphorus	1.15
Sulphur	.15
Sodium	.01

with a trace of chlorin, flourin, potassium, iron and magnesium.

These elements are obtained through the food eaten, the water drunk and the air breathed. About 65 per cent of the human body is water.

About half of the dry matter of plants is carbon. All foods contain carbon. Under certain conditions, carbon unites with oxygen, forming carbon dioxide, a gas which is present in the atmosphere. Leaves of plants take this gas from the air, thus tending to purify it. It is in this way that plants obtain their carbon, the one element which, it is now supposed, they do not take from the soil. Carbon dioxide is given off by germinating seeds and decaying vegetable matter and it helps to dissolve the plant food in the soil.

Experiments show that an acre crop of clover of 4,500 pounds contained 1.680 pounds of carbon derived almost wholly from the air, through the foliage. There is one pound of carbonic acid in two thousand pounds of air, so that all the carbonic acid in 12,320,000 pounds of air must have been consumed in producing the crop.

Prof. King shows that, as one cubic foot of air at a pressure of 29.922 inches and at a temperature of 62° F. weighs .080728 pounds, not less than 152,600,000 cubic feet of air must have been used. This amount of air would cover the acre to a depth of 3.503 feet, having a normal density.

Chapter XI

THE CHEMISTRY OF THE SOIL

Soil contains all of the elements given in the table below, of which the first ten are the most essential to plant growth.

Chemical Elements of the Soil

Carbon
Hydrogen
Oxygen
Nitrogen
Sulphur
Phosphorus
Potassium
Calcium
Magnesium
Iron
Silicon
Chlorine
Fluorine
Boron
Aluminum
Sodium

Few soils are deficient in any of the essential elements except nitrogen, phosphorus and potassium.

The problem of the cultivator is to continue to produce crops and maintain a sufficient supply of these elements, together with humus.

Wasteful Methods.—Some American farmers have been extremely careless and wasteful in the management of the soil, as illustrated by our worn out and abandoned farms in various states, and this in a comparatively new country.

Careful handling will, however, bring these depleted soils back to productiveness. In China and Japan the land has been under constant cultivation for thousands of years and is as productive now as ever, through careful handling.

Nitrogen Most Costly Soil Requirement.—Of the elements composing the nutrients used by plants, nitrogen is the most costly.

Plants absorb large quantities of nitrogen; drainage water takes considerable and some escapes in the form of gas.

In very rich soils there may be present nitrogen equivalent to 7,000 to 12,000 pounds per acre to a depth of one foot. At 20 cents a pound, this latter amount would be worth $2,400 per acre.

Soil with 10,000 pounds of nitrogen per acre may contain as little as 200 pounds of available nitrogen soluble in the soil water, of which only a part is utilized by the roots of the growing crops. Thus a soil may contain a large amount of nitrogen and be decidedly deficient in **available** nitrogen.

Organic Nitrogen may be present in exceedingly inert forms, as it is in some commercial fertilizers, similar to that in leather and as in many peaty soils, where there are large amounts of inactive organic compounds rich in nitrogen. Nitrogen of urea readily undergoes nitrification, while forms like that in peat nitrify with difficulty.

It is estimated that growing crops remove from the soil from twenty-five to one hundred pounds of nitrogen per acre annually.

Nitrates and Nitrification.—Nitrate is a compound composed of a base element such as sodium, potassium or calcium, combined with nitrogen or oxygen.

Crust on the soil prevents nitrification which is an additional reason for frequent cultivation. Moisture in the soil is also necessary, and as previously explained, cultivation tends to keep the soil moist.

The most favorable temperature for nitrification in the soil is between 54 degrees Fahrenheit and 99 degrees, but nitrification takes place in as low a temperature as 37 degrees.

Clay and loam soils tend to compact to such an extent as to exclude the necessary amount of air for nitrification, unless the soil is kept well tilled.

Nitrification on sod land proceeds slowly, but sod conserves nitrates, which are formed as fast as used and are not carried away by drainage water.

Land left bare rapidly loses nitrates through the drainage water, which is the reason why catch or cover crops are advisable during autumn and winter, to preserve nitrogen.

The **amount of nitrogen present** as nitrate in soils varies greatly. Rich garden soils may contain 60 or more parts per 1,000,000; cultivated soils 2 to 20 parts and pasture soils still less. The fluctuation is greater than in any other constituent of the soil. Rain and plants remove it and bacterial action forms it. The agencies producing nitrates are active from spring until autumn. The removal agencies are active in summer and winter.

Annual Loss of Nitrogen.—It has been estimated that the annual loss of nitrogen from all land under cultivation in the United States (which is not replaced by manure, by nitrogen supplied by plowing under of leguminous crops, by atmospheric precipitation by rain and snow and by the use of commercial fertilizer), amounts to between three and four million tons. To replace all this would require from fifteen to twenty million tons of sulphate of ammonia or from one hundred and fifty to two hundred million tons of ordinary commercial mixed fertilizer.

Organic matter added to the soil by manure or turning under green crops, remains near the surface unless carried down mechanically by some agency such as earthworms. At the Rothamsted Experiment Station in England, after fifty years of heavy applications of manure, the subsoil shows no increase in nitrogen. Another plot of land there, kept free from vegetation from 1870 until 1917, lost in the 47 years 2,376 lbs. of nitrogen in the top nine inches of the soil. The amount at the beginning was 3,500 lbs. and at the conclusion of the experiment 1,124 lbs.

Ammonia Compounds.—There are in the soil, organisms which have the power of producing ammonia from animal and vegetable bodies. The ammonia compounds produced are acted upon by nitrifying organisms and undergo nitrification.

Some plants such as peas, potatoes, corn and barley, are able to utilize ammonium salts (sulphate of ammonia) as a source of nitrogen, while others such as beets, take their nitrogen in the form of nitrates as nitrate of soda or nitrate of lime.

Chapter XII

ACID SOIL AND ITS TREATMENT

Micro-organisms present two phases to be considered, the action of the organism itself and the chemical action of the product of the organism.

The action of the organism causes a change in the organic matter of the soil, producing nitric acid. The nitric acid in the action upon the soil, produces nitrates.

An acid condition of the soil is injurious to the bacteria, it must be corrected by applications of lime to the soil, to prevent the valuable bacteria from disappearing. This is the reason why applications of lime are beneficial to alfalfa fields.

Bacteria will not be active when the soil contains injurious materials such as an excess of common salt or caustic lime or too large a quantity of borax, copper, zinc, etc.

Acids are injurious to most cultivated crops, some plants being more sensitive to acids than others. Nitrification may, however, take place in some acid soils.

Aluminum present in acid soils acts as a base and neutralizes the nitrous acid produced, forming aluminum nitrite and finally aluminum nitrate. This is poisonous to plant growth.

Acid soils are common in the humid regions, but are rare in arid sections. Some plants thrive in an acid soil, but most of the commonly cultivated farm and garden crops thrive only in an alkaline soil.

Acid condition of the soil is not likely where the land has good drainage, good tillage to insure proper aeration, and a balanced fertilizer ration.

Sandy soils, if acid, may require 500 lbs. of lime to the acre. On soil very rich in organic matter as much as 4,000 lbs. of lime may be needed. Usually a ton to the acre is a good dressing (30 to 40 bushels), and this not oftener than once in five years. Too frequent use of lime may be injurious.

How to Spread Lime.—Spread evenly over the whole surface and cultivate lightly after spreading to incorporate with the soil. If ground limestone is used, use double the quantity and see that it is fine enough to pass through a sieve having fifty meshes to the inch.

Ground or pulverized limestone and powdered lime, such as hydrated lime, can be distributed by means of lime spreaders made for the purpose.

Lime tends to bind the particles together and thus increases the water holding power of sandy soil.

See Other Chapters of this Guide for further information on this subject. Refer to Index.

Humus in the soil tends to overcome acidity and functions as an alkali.

Removal of lime and other elements by drainage and by the growing crops and the accumulation of acids from fertilizers are sources of acidity.

Muck or soils high in organic content and saturated with water are usually acid. Where drained and cultivated, the acidity is often corrected.

Decomposition of organic matter, which is almost continuous, except when the temperature is very low, results in the formation of dioxide and nitric acid. An insufficient supply of oxygen in the soil increases the acidity from decomposition.

The continuous use of ammonium sulphate and the use of sulphur, which is common for the prevention of potato scab, may result in acidity.

The presence of sheep sorrel (Rumex acetosella), is usually accepted as an indication of acidity. Other weeds which flourish in acid soil are:

Plantain, **Plantago major.**

Daisy, **Bellis perennis.**

Horsetail rush, **Equisetum arvense.**

Wood horsetail, **Equisetum sylvaticum.**

Goose grass, **Polygonum aviculare.**

Paintbrush, **Hieracium aurantiacum.**

Any of these plants growing in a field may serve to indicate acid soil, but not always does their presence prove that the soil is sour.

Organisms causing plant diseases are affected by soil acidity. Pythium, which causes "damping off" in seedlings and cuttings, is somewhat intolerant. No benefit and sometimes harm may be done by adding lime to affected soils in starting seeds of cuttings. The potato scab organism is also intolerant, which is the reason lime is not used on potato land.

As the roots of living plants are continually giving off carbonic acid, this might be expected to cause the soil to become acid, but on the contrary it becomes alkaline.

Chapter XIII

TESTING SOIL FOR ACIDITY

There are various ways of testing the soil for acidity. A reliable plan is to send a sample to the State Experiment Station where it can be analyzed, free of charge, and the proper application of lime and fertilizer suggested. This of course with the understanding that the land is properly drained.

State Agricultural Colleges and Experiment Stations.—Packages and letters addressed to Agricultural Experiment Station at any of the places listed below will receive proper attention. Communicate with the station in the state from which your communication is sent.

Auburn, Alabama.
Tucson, Arizona.
Sitka, Kodiak, Rampart, Fairbanks, Matanuska, Alaska.
Fayetteville, Arkansas.
Berkeley, California.
Fort Collins, Colorado.
Storrs, via Willimantic, Connecticut.
New Haven, Connecticut.
Newark, Delaware.
Gainesville, Florida.
Athens, Georgia.
Guam, Island of Guam.
Honolulu, Hawaii.
Moscow, Idaho.
Urbana, Illinois.

Lafayette, Indiana.
Ames, Iowa.
Manhattan, Kansas.
Lexington, Kentucky.
University Station, Baton Rouge, Louisiana.
North Louisiana Station, Calhoun, Louisiana.
Orono, Maine.
College Park, Maryland.
Amherst, Massachusetts.
East Lansing, Michigan.
University Farm, St. Paul, Minnesota.
Agricultural College, Mississippi.
Columbia, Missouri.
Bozeman, Montana.
Lincoln, Nebraska.
Reno, Nevada.
Durham, New Hampshire.
New Brunswick, New Jersey.
State College (Freight and Express address Mesilla Park), New Mexico.
Ithaca, New York
West Raleigh, North Carolina.
Agricultural College (Freight and Express address) Fargo, North Dakota.
Columbus, Ohio.
Stillwater, Oklahoma.
Corvallis, Oregon.
State College, Pennsylvania.
Mayaguez, Porto Rico.
Kingston, Rhode Island.
Clemson College, South Carolina.
Brookings, South Dakota.
Knoxville, Tennessee.

College Station, Texas.
Logan, Utah.
Burlington, Vermont.
Blackburg, Virginia.
St. Croix, Virgin Islands.
Pullman, Washington.
Morgantown, West Virginia.
Madison, Wisconsin.
Laramie, Wyoming.

(Address package to "Agricultural Experiment Station," then give town and state as listed above.)

In taking samples of soil for analysis, the New Jersey Experiment Station suggests the following method:

Take a large piece of heavy paper, oil cloth or canvas. Take samples at six different locations over the plot to be sampled. Carefully remove from the surface of each spot from which the sample is to be taken, any surface debris. Cut with a spade to about the depth of cultivation, say five or six inches, a good spade full and lay it on the paper, oil cloth or canvas. Repeat the operation at five other locations. Mix all the six samples thoroughly and from the mixture take a pound or a little more and forward to the State Experiment Station, being careful to write plainly, the full name and address of the sender on the outside of the package.

If a part of the field or plot is known to be different from the other part, a separate sample should be sent from that part, in the manner described.

With the package, write a letter and mail it separately or stamped and attached to the package, but not inclosed in the package, stating:—the **name** and **address** of the sender; whether **owner** or **tenant;** the exact **location** of the farm area represented by each sample; **crops grown** on the land within the past five years; approximate **yield** per acre of each crop; when **lime** was last applied and in what amount; amount of **manure** and **fertilizer** used within the past five years; **elevation** and **drainage** conditions; and character of the **crops** to be grown in the **future.**

Litmus Paper Test.—Blue litmus paper can be obtained at any drug store for a few cents. Make sure from the druggist that it is good. Wash the hands well with soap and water, before handling and handle as little as possible. With a clean knife blade cut a slit in the damp soil and insert a piece of litmus paper in the slit. After about twenty minutes, remove the paper. A decided change to red indicates acid. (Perspiration on the hands may lead to a red change in the paper.)

A more reliable way to make the litmus paper test is to boil the soil in distilled water then test the solution so obtained by inserting the litmus paper.

Chapter XIV

EFFECT OF CHARACTER OF SOIL ON PLANTS

The varying character of soil of the same type in different localities has a marked effect on the plants, although there may be no perceptible difference in the appearance of the plants.

It has been noticed in England, for example, that certain pastures fatten sheep well in summer. All about these pastures are others with exactly the same type of plants, but the plants grow more slowly, producing more stem and less leaf and are less nutritious and incapable of fattening sheep. The soils seem to be identical. In other pastures the vegetables cause diarrhoea, while similar vegetation on adjoining pasture does not.

It is possible that a considerable difference may be found in vegetables and fruits from different farms in the same locality.

Specialists have recently discovered the importance of vitamins and the foods which contain them and later may establish a method of determining the exact food value of fruits and vegetables from different types of soils and different soils of the same type.

Many crops will not thrive on acid soils, these include:—

Alfalfa
Red Clover
Timothy
Kentucky Blue Grass
Corn
Oats
Parsnip
Pepper
Pumpkin
Salsify
Squash
Spinach
Beets
Barley
Sorghum
Celery
Currant
Cabbage
Caulifower
Cucumber
Lettuce
Onion
Okra
Tobacco
Kohlrabi
Peanut
Egg Plant
—and most flowering and ornamental plants

Some plants require acid soil or do not object to it. It is beneficial to all the Ericaceae family, which includes:

Huckleberry
Blueberry
Cranberry
Heath
Wintergreen
Azalea
Arbutus
Andromeda
Sorrel Tree
Kalmia
Rhododendron
Acacia

Other plants that do not object to slight acidity include:

Strawberry
Blackberry
Turnip
Watermelon
Rhode Island Bent Grass
Red Top
Potato
Sweet Potato
Carrot
Radish
Velvet Bean
Ferns
Raspberry
Blackcap
Soybean
Cowpea
Hairy Vetch
Crimson Clover
Rye
Buckwheat
Millet
Lupine
Castor Oil Bean

A proper selection of the plants in the table last given, above, may make it possible to cultivate acid soils profitably, where the expense of correcting the acidity would be greater than the owner could afford.

The ericaceae are particularly suitable for soils too acid for other crops. This family includes the cranberry, huckleberry, blueberry, and others in the table given above.

Some of the composite plants do not seem to object to slightly acid soil. The compositae is the largest natural order of plants, containing more than 10,000 species, estimated at about one-tenth of all the flowering plants. The Dandelion is of this family. See a botany guide for a complete list of these plants.

Action of Lime.—Lime neutralizes acidity of the soil, or as generally stated, "lime sweetens the soil." Lime checks some plant diseases, but may promote others as it does in increasing scab in potatoes.

Lime is limestone or oyster shells, and it is used in several different forms. Quick lime is unslaked lime, also called lump lime. Ground lime is lump lime, ground. Water slaked lime is lime slaked by wetting. Hydrated lime is lump lime, ground fine, screened through fine sieves and hydrated commercially. Adding the water or hydrating, adds 32 per cent to the weight. Thus 100 lbs. of lump lime when hydrated will weigh 132 lbs. When hydrated, the lime is packed in paper bags. Air slaked lime is lump lime which has been exposed to the air. Ground limestone is limestone ground to a fine powder. Oyster shells when pulverized have the same value as pulverized limestone.

Soils respond much more readily to lime than to ground limestone. The use of lime results in the loss of nitrogen, through causing the rapid decay of organic matter and therefore should never be used on freshly manured land.

Lime is more effective in granulating clay soils than is ground limestone.

Marl and gypsum are forms of lime, but are not promptly effective in correcting acid soils.

Abundance of rainfall causes excessive leaching of plant food materials from the soil. Calcium is the plant food most easily leached. Semi-arid soils, as a rule, when well supplied with limestone are rarely acid. This leaching is hastened by the solvent action of carbonic acid gas, formed in the soil by the decomposition of organic matter, which converts the calcium compounds into soluble calcium bicarbonate.

Soluble iron or aluminum compounds are detrimental to plant growth and occur in harmful form in the absence of calcium.

The amount of calcium and magnesium removed in the crop from one acre, is given below, expressed in pounds per acre:

Crop	Weight	Calcium in Lbs.	Magnesium in Lbs.	Equivalent to Pure Limestone in Lbs.
Alfalfa	4 tons	114	15	345.
Clover Hay	4 tons	117	31	416.
Oats	50 bu.	1	2	11.5
Oat Straw	2½ tons	15	7	65.5
Wheat	50 bu.	1	4	18.5
Wheat Straw	2½ tons	9.5	4	39.8

A four ton crop of any of the common legumes removes from 120 to 140 pounds of calcium. Analysis has shown that alfalfa, grown on well limed land, contains fifty pounds of calcium per ton.

Calcium and magnesium are supplied to the soil by the use of lime.

CULTIVATING CORN TO CONSERVE MOISTURE
Drainage and irrigation are both problems that confront every grower. Cultivation plays an important part in conserving soil moisture.

Chapter XV

DRAINAGE

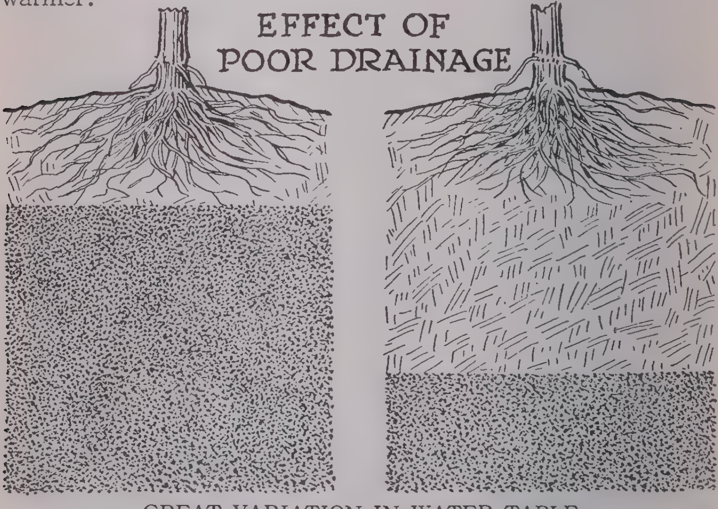
Drainage is the basis of permanent soil improvement.

The successful culture of the soil necessitates an ample supply of water for the crops, but not too much. Drainage must take care of all surplus. Where water remains after rains, or from snow and rains late in the spring, drainage must be supplied.

A FARM IN NEED OF DRAINAGE
Courtesy N. Y. State Col. Agriculture

Many fields drain naturally and the owner need give no thought to it. But, where there is excess moisture, this prevents aeration, keeps down temperature and is unfavorable to plant growth.

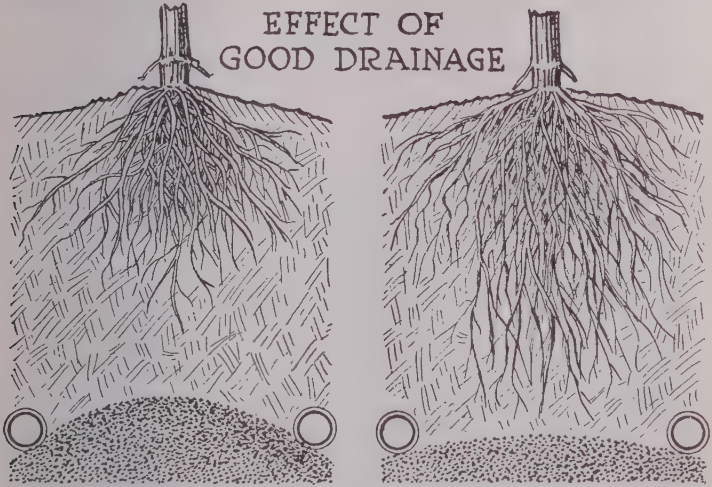
Soil warmth is greatly increased by proper drainage and its importance can be illustrated by a simple experiment. Put a teaspoonful of sugar in a half glass of cold water, observing the time taken to dissolve it. Then try the same experiment with warm water and notice how much quicker the sugar dissolves. In the same manner, in a warm soil, stronger solutions of plant food are formed more rapidly than in cold soils, thus drainage increases crop production partially through making the soil warmer.



GREAT VARIATION IN WATER TABLE
Roots flooded and starved in turn, stunting the growth

Where superfluous water remains on or in the soil, it must be drained away before satisfactory crops can be produced.

An indication of needed drainage is shown where the soil tends to puddle and bake when dry. Heaving is another indication. Winter kills grass in meadows where the drainage is poor. A field of weeds able to survive this condition results.



SLIGHT VARIATION IN WATER TABLE
Good drainage keeps water table at an even level

Poor growth of crops shows the low spots in fields where drainage is needed.

Some hillsides of porous soil may need drainage if the subsoil is sufficiently compact to hold the gravitation water. Any wet land, wherever it may be, needs drainage to make it fully productive. Even swamp and marsh land can be made tillable by proper drainage.

It does not pay to invest the necessary labor to prepare land, pay for seed and fertilizer, and spend time cultivating land that is not properly drained naturally or artificially.

In considering drainage, not only the surface water must be reckoned with, but also the water of the subsoil to the depth to which the roots penetrate.

Few farmers or gardeners realize the depth to which plant roots will reach in favorable soil. Roots of clover, timothy, barley, oats, winter wheat and corn spread their roots through the upper three feet or more of soil.

Heavy clay soils especially need drainage to take the surplus moisture, to warm the soil, prolong the growing plants and to make the soil more friable and increase aeration. This enables the plant roots to have greater penetration and greater root expansion which supplies the plant with just that much more food and increases the yield correspondingly.

Good drainage improves the physical condition of the soil, causing the retention of a larger amount of film water, which in dry seasons is needed by the growing crops.

Another advantage of retaining film water is that in the drier, warmer, better aerated soil, beneficial bacteria thrive and organic matter decays more rapidly, becoming available for plant food, releasing the mineral elements so they also may benefit the plants.

Heaving of plants through freezing and thawing is an indication of moisture in the soil. Unlike metal, water expands in freezing, and in moist soils the surface rises when frozen, lifting the plants and tearing the crowns from the roots which are held fast in the deeper soil.

The trouble can be corrected by drainage and drainage may be said to be the foundation of permanent soil improvement.

Chapter XVI

OPEN DITCH DRAINS

Where the volume of water to be carried away is very large, open ditches may be used. This is the system by which large tracts are drained as in the states of Indiana and Florida, or where the land is flat, and to be effective sufficient depth must be maintained. Where land is valuable, that wasted by the ditches should be considered, also the work of keeping the weeds along the banks, under control.

OPEN DITCH IN WISCONSIN CRANBERRY FIELD
The soil from the ditch was used to build the dike

Under drains cost less to maintain and are more permanent than open ditches. Drains laid near Geneva, in New York State in 1835, are still in successful operation.

Surface operations are not disturbed by underdrains and they keep the soil in condition to a greater depth than open ditches.

Shallow ditches consisting of a deep furrow made with a plow, sometimes answer for removing small accumulations of water. Dead furrows are sometimes left, dividing the field into somewhat narrow beds to carry off some of the surplus water.

Where large open ditches are used, the size must be in proportion to the area to be drained, with the sides inclined sufficiently to prevent caving of the banks.

Keeping the ditch as straight as possible, to prevent washing or erosion of the banks, which is likely where there are curves, is essential. Where curves must be made, make them as gradual as possible. Steep grades should be avoided as they lead to washing out the soil.

Three feet per second is the maximum velocity of the flow considered safe, and less than this in sandy soil. A fall of eight to twelve inches in the mile gives this velocity in ditches of deep water, while in small ditches carrying water a foot deep, the grade may be as great as sixty feet to the mile.

A strip of grass not less than five feet wide should be maintained on each side of ditches of good size, to prevent washing from the water flowing into them, at times when the flow over the banks into the ditch may be considerable.

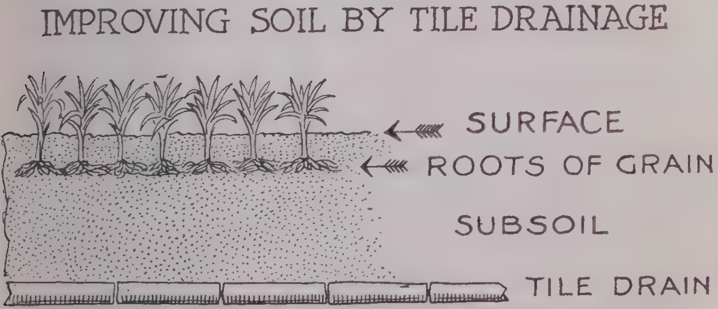
Even where land is underdrained it is often a good plan to have some surface drains (shallow ditches with low, sloping sides), so as to be grassed over. Each field presents its own problems, which must be carefully considered and handled according to requirements.

Chapter XVII

TILE DRAINS

As tile drains are the most generally used, being the most permanent and satisfactory type of drain, it is well to give careful and detailed attention to this subject.

Tile drains are made of burned clay or concrete, in short round sections. These should be placed in the ground low enough to lower the water table to the desired depth. The line should be carefully graded and kept straight. If curves must be made, make them as long as possible, carefully avoiding short turns which are apt to be troublesome. Protect the joints on outer turns, where that side may be too open.



THE TILE MUST BE PLACED BELOW THE FROST LINE

Tile is made of soft, absorbent material and unless down safely below the frost line, will be broken when saturated with water and frozen.

Water enters the tile at the joints and through the pores, by absorption. Near trees, where tree roots are likely to work into the tile and obstruct it, the joints should be covered with cement. Poplar, larch, willow, water elms and even maples are dangerous near drains of constantly flowing water. As far as possible, these should be removed along the lines of drains, if the trees are sufficiently near for the roots to enter and clog the drain. A poplar tree sent its roots fifty feet under a hard paved street in Newark, N. J., and completely clogged a six-inch sewer pipe.

The foundation for the tile should be firm and if the bottom of the trench is soft, cinders, gravel or boards should be used to preserve proper alignment of the tile. **Conditions must be studied** for each drainage system, also the movement of the water, planning the drainage system so it will be most effective. The main lines should be located to intersect any troublesome springs or particularly wet or low spots and so the main drains will run lengthwise of the field, with branch lines run out diagonally. On sloping land the drains should extend up and down, not crosswise.

Tile drains should be set on a grade of one to two feet in a hundred, when that is possible, and not less than six inches to the hundred feet, and from three to three and a half feet deep, or deeper, for deep-rooted crops. On heavy clay, only two feet deep may give proper drainage.

Where drains are set three feet deep, the space between drains should be about sixty feet. The shallower the drains, the closer they should be together.

Where tile drains are laid forty feet apart 1,089 will be required per acre; fifty feet apart, 870; eighty feet, 545; one hundred feet, 435.

Do not be disappointed if the soil conditions do not improve as much as expected immediately after draining. It sometimes takes two or three years for the soil to get into its best condition.

Good underdraining, particularly operations conducted on a large scale, requires thorough knowledge and experience. One accustomed to the work can quite accurately determine the place for mains and lateral drain lines, after making a survey.

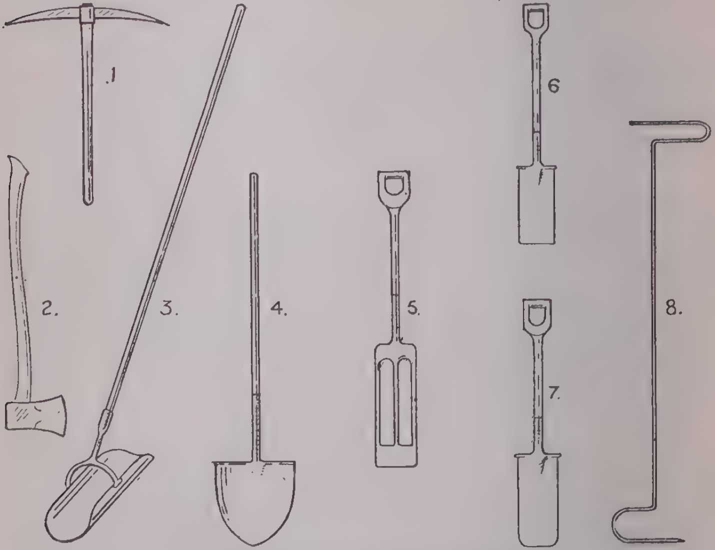
Where large areas are to be drained and particularly on nearly level land, it is best and cheapest to employ an engineer to do the leveling, determine grades, set the stakes and do the work with a crew of trained men. Each man in the crew makes a specialty of his particular work; one finishes the bottom, others lay the tile and so on. When completed the job is right and later trouble is avoided.

In employing a contractor to do the work including the surveying, trenching and laying the tile, at so much per hundred feet, the contract should be in writing stipulating whether the owner or contractor furnishes the tile and kind of tile; that the contractor furnish all his own tools and do the work accurately according to survey and subject to inspection by the owner or his representatives.

Defects in drainage work sometimes do not show until long after the work is completed and to correct them may be expensive. The land owner should endeavor to know enough about the work to see that the engineer employed carries out the operations properly.

Where small areas are to be drained and the fall is ample, the owner may do the work himself or with the help of his men.

In such cases, a preliminary survey can be made with a tape line, before the work is begun.



TOOLS USED IN DRAINAGE WORK

1. Pick Axe
2. Axe for cutting tree roots
3. Tile Hoe, or Scoop for grading bottom of ditch
4. Long handled, pointed shovel
5. Ditching Spade
6. Ditching Spade
7. Ditching Spade
8. Tile Hook

A careful estimate is then required of the size of tile and number required; the necessary angles for connecting lines before the order is placed. When the tile is received it should be placed in the fields, before the leveling for the work is done. This prevents trouble from the grade stakes being broken in the delivery of the tile after the survey has been made.

Construction of Tile Drain.—With the grade established, the tile on the ground, the ditch is ready for digging. Each step must be carefully taken as the work, when properly done, will last for generations.

Tools.—Ditching spades are made especially for tile ditching and, in addition, a round pointed, long handled shovel, a tile scoop and tile hook will be needed, also possibly pickaxe, axe for cutting roots, a mattock and crowbar for prying out large stones. A sledge hammer may be required for breaking up large stones so they can be handled more easily. Digging and finishing the ditch is sometimes done with an ordinary shovel. Lines for lining and grading the trench will also be needed.

The tile scoop is used to finish the bottom of the trench and shape it to receive the tile. It may be had in different sizes, to fit the size of tile to be laid.

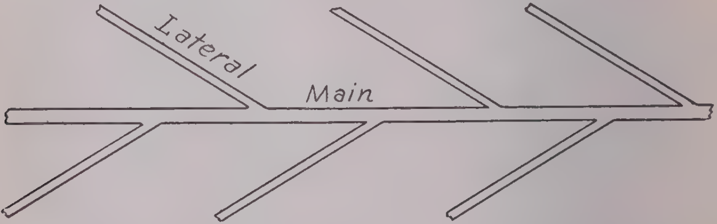
The tile hook is used where the tile is laid from the surface. With it the tile are put in place without getting into the trench. This system permits making narrow trenches, saving work in digging.

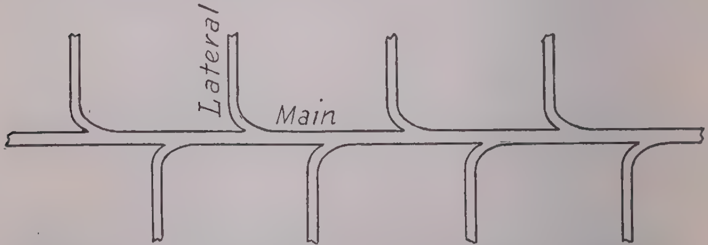
In stony land or where there are many roots, hand labor only can be used and dynamite may possibly be used to advantage. On suitable land where the operation is large enough, a ditching plow may be used advantageously. On very large operations ditching machines are employed that cut trenches very rapidly.

A good drainage level which at the present time costs about $25.00 is required in tile drain work. Also a graduated target rod which costs from $8.00 to $15.00.

Trenches should be as small as possible, to save labor, and still permit conveniently laying the tile. Where small tiles are used, the trenches are usually made about a foot wide, with vertical sides.

In large operations the heaviest work is done with plows and horses or machines operated by an engine.





IF TILE DRAIN LINES ARE AT RIGHT ANGLES TO THE MAIN
They should be curved before meeting the main

In laying out tile drains, where lines join, never have the joints at right angles, but on a slant or acute angle. **See illustration.**

If the lines must be at right angles, turn with a curve before joining. **See illustration.** This prevents the collection of sediment which might fill the drain tiles. Junction pieces may be had for this purpose.

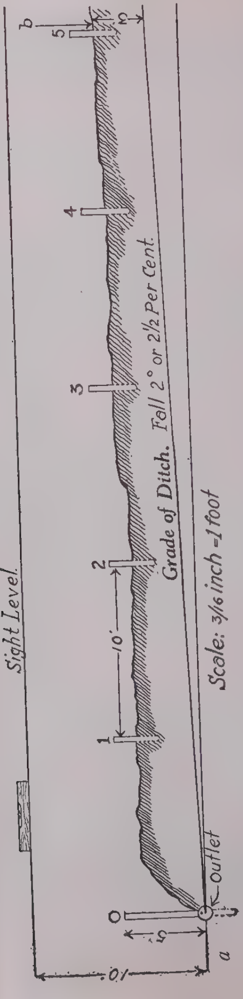
Give a little drop or slant to the side drains where they enter the main line.

Surveying.—Surveyors use what is known as a Y level. This instrument is expensive and cannot be used correctly by everyone. Several cheap levels are made, called drainage levels. They are not as accurately made as Y levels, but they answer for use where there is a fair fall.

Leveling rods are from eight to ten feet long and graduated to one one-hundredth of a foot. That is, the foot is divided into one hundred equal parts. It is an easy way of figuring. One one-hundredth of a foot is about one-eighth of an inch. Exactly 8×12=96, so if one one-hundredth of a foot is considered as being equal to one-eighth inch, the measurements will be four one-hundredths of a foot out of the way to each foot. This in a foot is not much, but carried over long distances would be considerable.

If much leveling is to be done the best plan is to purchase a cheap leveling rod. The leveling rod is equipped with a target, a circular plate divided into quarters, which are painted alternately red and white. The target slides up and down on the rod and is held in position by a clamping screw. The center of the target is open to expose a portion of the center of the rod.

Home Made Level.—A carpenter's or mason's straight edge and level will serve very well, if only a moderate amount of



LAYING OUT A DRAINAGE DITCH
See text on opposite page for explanation

drain is to be laid. A leveling rod will also be required, marked in feet, inches and feet divided into eighths or hundredths of a foot.

In the diagram shown on opposite page, the ditch is 50 feet long. A sight level is established with a straight edge on which a carpenter's level is used to assure the straight edge, which is turned up, being exactly level, so sighting over it will be correct.

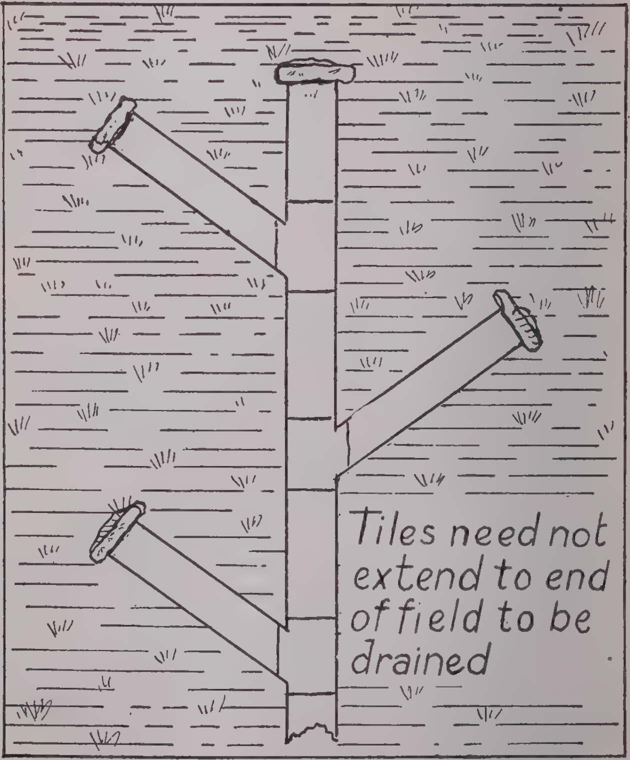
In this diagram the level is ten feet above zero, the point where the outlet is to be located. The surface of the land is sixteen inches lower at "a" than at "b" and the land elevation has a fall of eight inches less than the ditch to be dug.

The simple way is to disregard the grade of the land and to set the stakes by which the ditch is to be dug, so the top of each stake is a given distance above the bottom of the trench to be dug. In this diagram it is five feet. The distance between each stake is ten feet, therefore each stake is four and four-fifths inches higher than the one below it.

The amateur can easily find the grade by the use of a true straight edge and level, by dividing the distances by the amount of grade and leveling from stake to stake, driving them as shown in the diagram, so the top of each stake will be the same distance from the bottom of the trench to be dug. In the case described, the top of stake **zero,** is five inches lower than the sight line and stake **one** is four and four-fifths nearer, or seven and one-fifth inches from it.

The lines having been properly leveled and staked out, to insure laying the tile at the proper level, the ditches are dug, the bottom carefully finished with a grading scoop, on a firm bed of earth. The grade should be kept as uniform as possible.

The end of the main line or that of the laterals need not be run to the farther end of the area to be drained. The water in the soil will move toward the end of the line, over a considerable area. The end of the main and those of the laterals should


Tiles need not extend to end of field to be drained

CLOSE ENDS OF MAINS AND LATERALS TO PREVENT CLOGGING be covered with a flat stone or otherwise almost completely closed to prevent the soil from entering and clogging up the line.

Where surface water is admitted to tile drains, screens of some kind should be used to prevent any material entering and stopping the drains.

Drain at Different Levels.—On areas where the contour is broken, it may be necessary to divide the drain into sections, each section on a separate level, the fall of each section to be determined separately. Where breaks of this kind occur in the grade, silt basins will be required, where the levels or lines of different grades join.

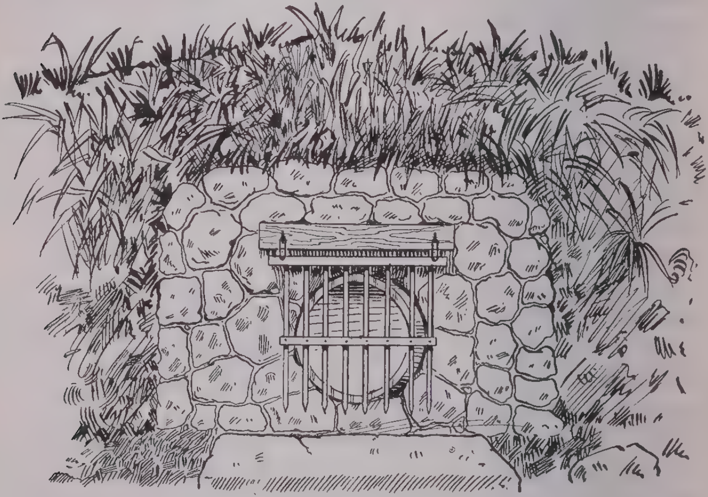
Placing the Tiles.—In shallow trenches, small tiles are placed by hand; or, by means of a hook if the trenches are deep. Place the ends of the tile closely together and fit them to make a close joint. The laying of the tile should begin at the outlet and proceed toward the upper end.

The ends of the tile are not always square. Where a tile does not fit squarely and snugly, turning the tile will generally fit it sufficiently tight to prevent the soil from entering. If this cannot be done, another tile should be used. The discarded tile will likely join properly with some other, later on. If the joints are open, sand will work through and clog the drain in time.

Blinding.—Blinding might more accurately be called binding. As the tile is laid, carefully shovel in sufficient loose earth to cover the tile and hold it in position until the trench is filled. If the filling is long delayed, the trench is likely to cave in.

Outlets.—Have as few outlets as may be necessary with tile drains and these should be firmly set in stones laid in cement.

In cold climates the outlet of the main drain should be laid in masonry. The action of frost will crumble unglazed clay tile. Glazed sewer tile should be used for the last ten feet of the drain or masonry to insure permanency.



DRAIN OUTLET.

THE BARS PREVENT SMALL ANIMALS FROM ENTERING

The end of drain outlets should be covered in some manner, with heavy open mesh screen or metal bars to prevent animals from entering.

Where there is no other outlet for tile or open drains to empty into, deep wells are made and filled with large stones to form the drain outlet. A well or reservoir can be made in such cases, the collected water being used for irrigating.

Tile Size.—The proper size of tile to use depends upon the quantity of water and rate at which it must be moved, the character of the soil, the grade and length of the drains, their depth in the ground and whether the main course is straight or curved.

The size most generally used is four inches in diameter. Smaller tiles are likely to become clogged.

The main line must increase in size, in proportion to the volume of water introduced by the different laterals.

If naturally wet places or springs are to be drained, they must be considered in calculating the size of drains, including the natural rainfall.

A long drain has less carrying capacity than a short drain of the same size, laid upon the same grade.

Three inch tiles, in lines not more than 500 feet in length, are usually used for laterals. Four inch tile is used up to 1,500 feet, with a grade of 4 inches per 100 feet.

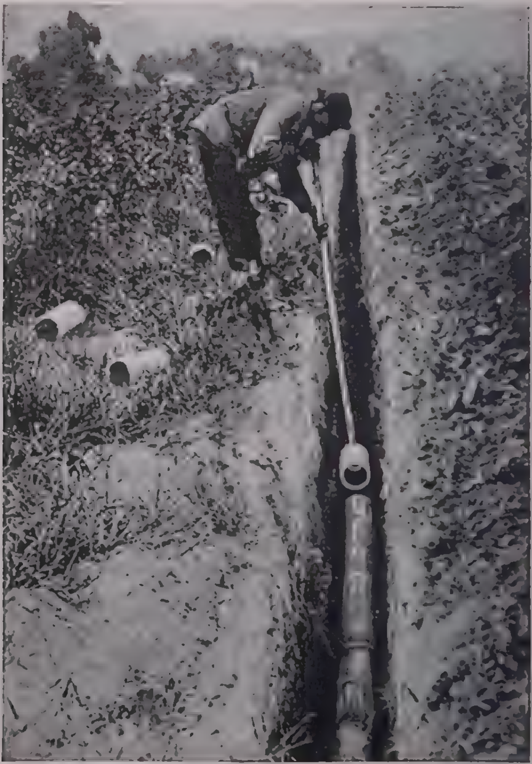
Doubling the grade per 100 feet increases the capacity about one-third. Lowering the grade decreases the capacity one-quarter.

Drain tiles range in size from 2 inches upward. The capacity of different sizes to carry water, with constant rate of flow, varies according to the square of the diameter. To find the square of the diameter, multiply the diameter by itself.

A 4-inch tile is $4 \times 4 = 16$ as the square of the diameter. A 2-inch tile, $2 \times 2 = 4$. A 4-inch pipe will carry four times as much water as a 2-inch pipe, each having the same grade or fall.

Do not use tile with collars for drainage.

The conditions that determine the size of drains are: **Depth of water** to be removed in twenty-four hours over the area of



ILLUSTRATING USE OF TILE HOOK
in placing drain tile sections

the drainage system, and the **rapidity** with which the water is brought to the main—that is, the **number** of laterals and **amount of water** received through them.

Testing Drain Tile.—Good drain tile should be sufficiently hard to give a clear, sharp ring when struck with a piece of metal, after it has been exposed to the atmosphere for some time. The water will enter the drain at the joints, so the tile need not be porous, although porosity is an advantage.

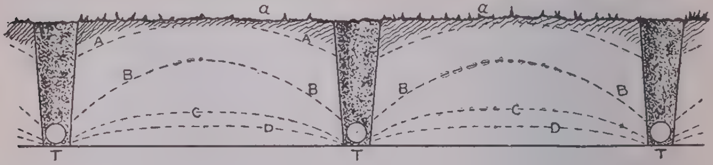
Home Made Cement Tile.—Molding machines are made that are not very costly, for making cement tiles. Home made cement tiles must be made with care and kept wet while curing. The mixture should be one part Portland cement to three parts sand. The tile should be cured for three weeks or more before using. Be careful to use only sharp, clean sand, to mix thoroughly, to pack carefully and tamp thoroughly.

Percolation through Tiles.—Experiments made at the Michigan Agricultural College show that water passes through cement tile, although the quantity may not be large. This can be tested by allowing water to run on a tile held horizontally and watching the inner surface.

Prof. King states that in a series of experiments to determine the rate of percolation through the pores of 2-inch clay tiles, under a pressure of 23.5 lbs., the discharge per 100 feet into the tile was at the rate of 8.1 cubic feet during twenty-four hours.

Effect of Drains on Water Table.—Underdrained lands dry the lands first near the drains. The successive lowering of the water table is shown in the diagram by the dotted line A A—B B; C C and D D. In open soils the water table may quickly lower to lines C and D, but in retentive soils the action will be slower and the drains will require being placed closer together.

Effect of Drains on Position of Water Table



The number of acres of land drained by outlet tiles, removing one-quarter inch of water in twenty-four hours, is as follows:

Diameter of Tile in Inches	Grade in Inches to a Hundred Feet					
	½ Inch Acres	1 Inch Acres	2 Inch Acres	3 Inch Acres	6 Inch Acres	9 Inch Acres
5	17.3	19.1	22.1	25.1	32.0	37.7
6	27.3	29.9	34.8	39.6	50.5	59.4
7	39.9	44.1	51.1	58.0	74.5	87.1
8	55.7	61.4	71.2	80.9	103.3	121.4
9	74.7	82.2	95.3	108.4	138.1	162.6
10	96.9	106.7	123.9	140.6	179.2	211.1

(Calculated by C. G. Elliott in "Engineering for Land Drainage.")

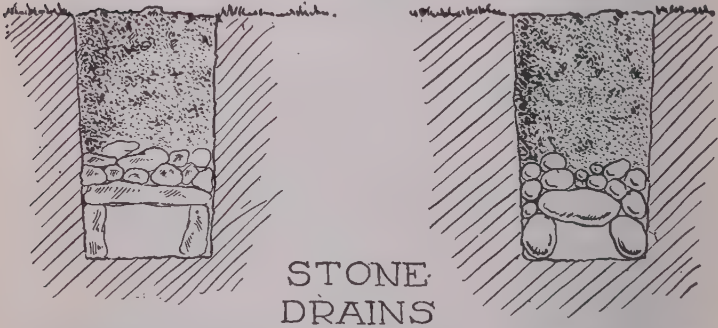
The following table from Prof. Fippin gives in a general way the area of different sizes of tile, laid at different grades:

Number of acres from which one-fourth inch of water will be removed in twenty-four hours, by outlet tile drains of different diameters and different lengths, with different grades:

Diameter of Tile in Inches	Grade in Inches per 100 Feet									
	1		2		3		6		9	
	Length of Drain in Feet									
	1,000	2,000	1,000	2,000	1,000	2,000	1,000	2,000	1,000	2,000
	Acres of Land Drained by the Different Sizes of Tile									
5	19.1	15.7	22.1	19.4	25.1	22.7	32.0	30.3	37.7	36.3
6	29.9	24.8	34.8	30.5	39.6	35.9	30.5	47.8	59.4	57.3
7	44.1	36.4	31.1	44.8	58.0	52.8	74.0	70.1	87.1	84.1
8	61.4	50.7	71.2	62.6	80.9	73.6	103.3	98.0	121.4	117.3
9	82.2	68.1	95.3	83.8	108.4	89.6	138.1	131.3	162.6	157.1
10	106.7	88.5	123.9	108.9	140.6	128.1	179.2	170.5	211.1	204.4

Limit of size of tile to grade and length

Size of Tile, Inches	Minimum Grade per 100 Ft.	Limit of Length of Tile in Feet
2	.10	600
3	.09	800
4	.05	1,600
5	.05	2,000
6	.05	2,500
7	.05	2,800
8	.05	3,000
9	.05	3,500



Stone Drains.—Where there are plenty of stones their disposition is often a source of trouble.

Stone trenches require a grade of not less than six inches to each hundred feet. The bottom should be clay or some other hard material.

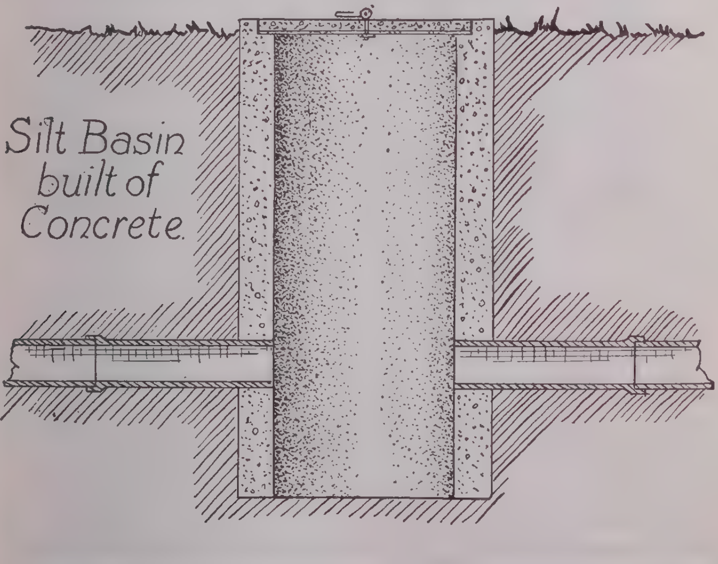
Stones are placed in the ditch to form the sides, topped by flat stones held in place by stone wedges on top of and at the sides of the top or cap stones. Other stones can be used over the cap or the trench filled wholly with earth.

Where the cost of labor is to be considered, tile drains can most likely be laid cheaper than stone drains.

Chapter XVIII

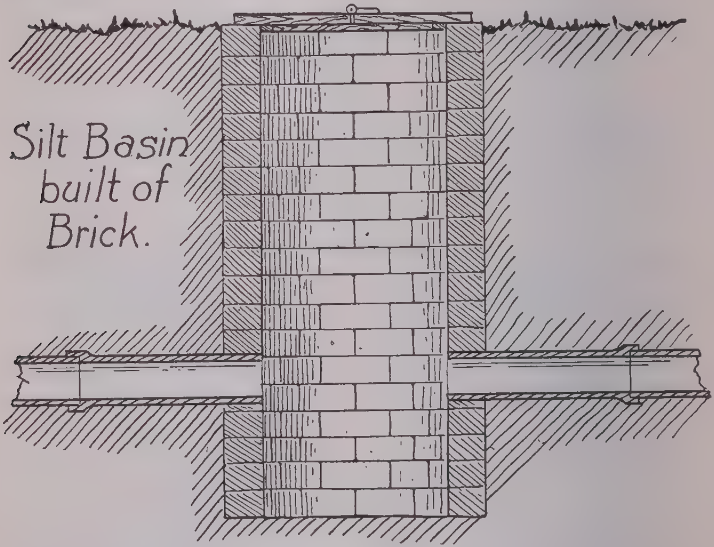
SILT BASINS

Silt Basins are used to prevent the clogging of the tiles by silt or sediment carried in the water and they afford a convenient means of cleaning out the drain if that is required.



Silt basins are placed wherever the line of drain is changed from a higher to a lower rate of fall and particularly where the flow below the point of change will be slower than in the line above, or where a long line unites with another.

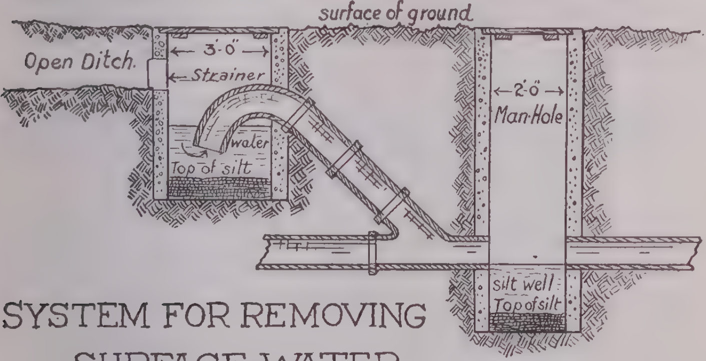
In case the lines become clogged, they can be cleaned from the silt basins.



If it is expected that it may be necessary for a man to get in the silt basin and work at any time, in cleaning out the drain, the basin should be three feet square or if circular, three feet in diameter. Otherwise, the basins may be only eighteen inches in diameter.

Silt basins may be of brick, stone or concrete and open on top or supplied with a cover. The bottom is best made of cement.

The bottom of silt basins should be a foot or more below the outlet tile. The water entering the basin is checked in its flow and the sediment it contains settles to the bottom, and it is then removed from time to time.



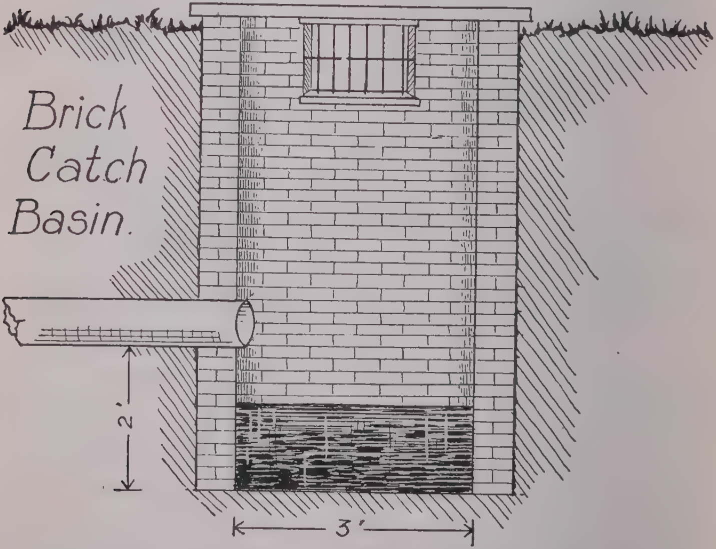
SYSTEM FOR REMOVING SURFACE WATER

THE INVERTED OUTLET IS NOT LIKELY TO CLOG

In irrigated land in tropical or subtropical climates, planted to vines and trees, the roots are likely to fill and stop the drains. Silt basins at every four hundred feet should be provided, so drains can be examined and cleaned. A wet spot in the field indicates drain stoppage.

Drains may be cleaned from silt wells by passing a root cutter through the drains as often as occasion may arise. The cutter is made of a cylinder of wood a foot long and of a diameter to fit the drain, covered with leather through which sharp pointed nails have been driven. A stout wire is forced through the drain, the brush fastened on one end, the other running over a roller at the bottom of the well and another at the top, is drawn by a horse. The operation repeated until the drain is clear.

Sediment basins are practically the same as silt basins, but are used where more sediment is expected in the flow. The well in this case is made two or three feet below the bottom of the drain. The outlet is through an elbow, turned down, so as to prevent the entrance of any large floating material.



Catch Basin.—A catch basin is a silt or sediment basin with an inlet near the top. The inlet should be at the side, near the surface of the ground and be screened by rods placed two inches apart to keep out coarse material. The catch basin is used in the removal of water from small ponds or where the soil is so heavy the water cannot penetrate. Catch basins should be placed so the water will not carry large quantities of earth into the drain.

Chapter XIX

DRAINING PEAT, CLAY AND MARSH SOILS

Draining Peat and Muck Soils.—As a rule these should be drained with open ditches. In these soils the capillary attraction is low, so care should be exercised not to get the water table too low for the growing crops.

Some irrigated lands require drainage, particularly alkali soil, where alkali salts have accumulated in the top soil as a result of irrigation without drainage. In such cases the drains should be deeply placed, five or six feet below the surface. Alkaline soils can be reclaimed by washing and leaching in this manner for two or three years.

Gumbo soils and very stiff clays do not drain well and in these cases, in addition to tile or ditch draining, subsoiling may be necessary. Cotton planters run a furrow between each row of cotton, as soon as the seed is planted, even where the land is underdrained.

Clay Subsoil Layers and Use of Explosives.—Sometimes areas will be wet on account of a layer of clay that retains the water, while below may be porous earth, such as sand or gravel. If the impervious layer can be broken through in places, so it will not stop up again, this may be the only drainage needed. This result is sometimes successfully accomplished by the use of explosives. Explosives are frequently used in opening ditches three feet or more in width, and are of greatest value in rocky land or land filled with stumps.

Salt marshes are lowlands along the sea coast that are subject to overflow of the tide. Where these are near large cities they may be profitably diked to keep out the high tide and drained by open ditches. Gates should be provided which may be closed at high tide to keep the water out and opened at low tide, to empty the drainage ditches. Usually in such locations the wind is quite dependable and wind mills can be used to pump the water from the ditches over the dike, or an engine used for the purpose where this is required.

Drainage of salt marshes, as of other lands, provides greater depth of soil, giving an extended root range and improved soil texture, producing a warmer soil, better aeration and promoting activity of beneficial soil bacteria. The land is made fertile and early, as such soil when freed from salt, is usually rich. Waste land may be made productive and profitable by drainage.

The removal of stagnant water from salt marshes destroys mosquitoes, which cause malaria and yellow fever. Drainage changes unsanitary wastes into valuable helpful locations.

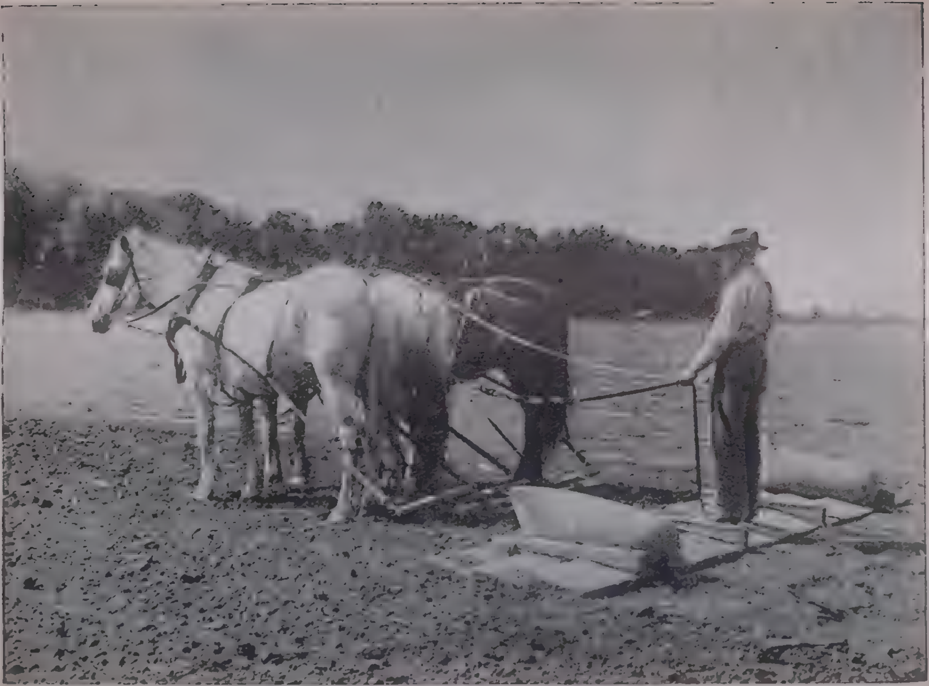
Two years will be required to free salt marshes of salt and is accomplished by rainfall washing the salt out through the drains. Rye or sorghum should be the first crops, as they seem to be able to stand salt better than most crops.

In Illinois and in Indiana, the fields for many square miles are almost level, so it is difficult to provide adequate drainage. Here the citizens combine, and broad, deep, open ditches are made many miles in length, providing outlets over the whole territory for underdrains.

Crossing two counties in Illinois is a ditch, seventeen miles in length, eight to eleven feet deep and thirty to sixty feet wide at the top, with five laterals, about nine feet deep and thirty feet wide at the top. The yield in grain in this territory has more than doubled. Not only in yield per acre has there been an improvement, but land formerly too wet to operate has been reclaimed to cultivation.

It is estimated that the farmers of Iowa have spent as much for tile drainage as the cost of the Panama Canal.

SHRINKAGE CRACKS IN HOLTVILLE CLAY
Surface was deposited by overflow of Colorado River. Palo Verde, Riverside Co., Calif.—U. S. D. A.



HOME MADE PLANK CLOD CRUSHER

Chapter XX

NOTES ON WATER AND DRAINAGE LAWS

Surface water is water before it enters the soil, running off over the surface. When it enters the soil it becomes gravitation water.

Gravitation water is water in the soil that will flow downward or away through the soil by its own weight. Obstructions may cause it to flow in other directions.

Capillary water is the water remaining clinging to the walls of the soil particles after gravitation water has passed away.

Hygroscopic water is the water found in the soil after it becomes air dry, that is, as dry as the atmosphere. The movement of hygroscopic water is called thermal movement, because it is caused chiefly by heat from the surface of the soil.

Proper Water Content.—According to Helbriegel the best moisture conditions of soils for maximum growth of crops are:—fifteen per cent of their own dry weight for sandy soils; thirty per cent for clays; and twenty per cent for loams.

One hundred pounds of loam with twenty per cent of water will weigh 120 lbs. One hundred pounds of water require five times as much heat to raise its temperature one degree as one hundred pounds of soil. Properly moistened loam will require twice as much heat to raise its temperature as it would if the soil were dry.

Warm Soils.—Sandy soils carry less capillary water than loams or clays, and for that reason rise to a higher temperature with the same heat. It is on this account that they are called warm soils.

Cold Soils.—Wet soils carry an excess amount of water which keeps the temperature down, because more heat is required to raise the temperature of water than dry earth.

Water Table Falling.—It is claimed by some meteorologists that cutting off of our forests has not affected the flow of rivers, the retention of moisture in the soil or the rainfall. It seems, however, that this would be the natural result. It is certainly proved by actually demonstrated facts that streams which once flowed in considerable volume have disappeared. Even good sized lakes, such as Silver Lake, in the town by that name in Essex County, New Jersey, has vanished. Wells that once supplied an abundance of water have gone dry.

From facts gathered from 29,000 wells located in 48 states, W. J. MacGee, Bulletin 92, U. S. Bureau of Soils, shows a very marked fall in the ground water level.

Forests hold the snows of winter until late in spring by affording shade from the rays of the sun. When the snow in a forest or piece of woods finally melts, the moisture is long held in the soil through the shade afforded and because of the protection from drying winds.

Investigators in Europe and in some other countries indicate that there is an appreciable increase in rainfall as a result of reforestation.

It is claimed by old residents of various sections of the country, originally heavily wooded, that the cutting away of timber and draining the land has greatly lengthened the period between late spring and early autumn frosts.

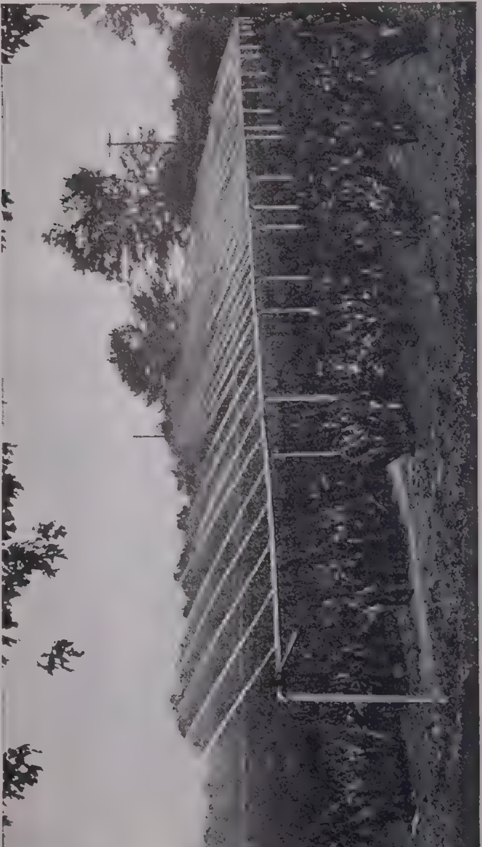
Drainage Laws are different in different states. Generally, a property owner is permitted to drain his land in the general course of natural drainage, by means of open or covered drains, discharging them into any natural water course, or any natural depression whereby the water will be carried into a natural water course, when such drainage is wholly upon the owner's land. This may not include the sewage from house or barns.

There are variations of this general procedure, as some states maintain drains and the consent of the commissioners is required before drains may enter them.

Some states permit a land owner the right to drain across adjoining property where necessary. Where it is possible, it is advisable to have an understanding with the owner of adjoining land, over which drains are to be conducted, to have the agreement in writing, signed and witnessed. It is a case of "an ounce of prevention is worth a pound of cure."

Where it is impossible to reach an agreement, the law probably will provide a way to settle the matter. On general principles, avoid law suits.

OVERHEAD AUTOMATIC IRRIGATION INSTALLATION



(White Showers)

Chapter XXI

BENEFITS OF IRRIGATION

Irrigation is the Watering of the Land.—It is the opposite of land drainage, which is the withdrawal of surplus water. Each is equally important.

Plants and animals are composed largely of water and no form of life can survive without it. In plant life, water is the medium through which the transformation of raw materials into food materials takes place. It is by means of water that food products in the soil are transported to the locations where the plants grow.

Animals move about for their food, but the higher orders of plants have their food brought to them through the medium of water. It can be understood from this how important it is that plants have the proper amount of water at all times to insure bountiful crops. Too much and too often, or continual wet, or insufficient water, acts on plants as too much or too little food constantly supplied to a human being. Sickness and a premature end result.

Farm crops generally depend on the natural rainfall for water. Rains are irregular. Sometimes rains are continuous over extended periods, raining every day or so for a month, or more.

At other times, even when the yearly precipitation is considerable, there may be weeks without rain, when crops suffer severely or fail. In the East, a period of two weeks without rain, in the growing season, may be serious.

Drainage takes care of the surplus water on areas not drained naturally, and **irrigation** supplies water in dry times, to make soils produce larger yields.

Soils vary greatly in character. One may be benefited by drainage and another by irrigation. Another soil may require both drainage and irrigation.

The crop to be grown must be considered. Some plants prefer soil of coarse texture, retaining only small amounts of water, while others require a finer texture of soil and more water. Finally, it must be considered whether the increase in the crop by irrigation will pay for the expense of irrigating.

The advantage of an ample supply of water is shown by the prolific grass crops on clay soils in seasons of continuous spring rains, which are far greater than on heavily fertilized land in dry spring seasons. The same is true with other crops.

In humid regions, where the subsoil is water soaked, the nitrogen forming bacteria, for want of air are forced close to the surface. If the surface is then permitted to dry, the nitrifying process ceases and the crop suffers, although the plants may have sent their roots down into the damp soil to obtain moisture.

When irrigation is supplied by rain or artifically, the nitrates formed are washed down where they are available to the deep roots of the plants and they are thus saved to the crop.

In soils well supplied with organic matter, nitrates are formed in large quantities and the soil water carries so many salts that it is no longer suitable for the use of the bacteria. If, however, water is supplied, the salts are washed downward where they are absorbed by the deeper plant roots and the fresh water induces increased bacteria activity and thus promotes plant growth.

If the soil, in such cases, is not properly drained, the roots of the plants are forced to the surface and all of the nitrates washed downward will be wasted.

With the roots close to the surface, in dry times, the plants absorb all the moisture, which checks the action of the bacteria and this in turn checks plant growth.

Water exposed to the air is charged with oxygen, carbonic acid and nitrogen which add to fertility of the soil. It has been shown that plants are composed largely of water and therefore the importance of water to growing crops may be realized.

Too much water causes the exclusion of air; reduction products are then formed by bacteria which have a toxic or poisonous effect on plants.

Growers of tomatoes under glass regulate temperature and water supply, so as to produce compact bushy plants, which give more fruit than large, soft plants resulting from other conditions. Vigorous growth is not encouraged until the blossom is fertilized or set. Vigorous growth is checked by withholding water, keeping the atmosphere of the house damp, supplying directly only what water is absolutely necessary. After the fruit has set, water is supplied liberally and top dressings of manure applied.

Dry Period to be Considered.—It is not alone the amount of rainfall, but the distribution during the growing season that determines whether irrigation may or may not be profitable. The dry period which may affect the growth of crops is the important consideration.

The object of irrigating is to insure proper moisture relations, essential to plant growth throughout the entire growing season. Some crops, like the cranberry, are benefited by complete inundations. Others, like the pineapple, are grown on soil that leaches and retains but small quantities of water, so that even frequent rains must be supplemented by irrigation to obtain profitable crops.

Water Requirements.—In considering irrigation and water supply, the question naturally arises as to what the actual water requirements on a place are. The human beings and live stock as well as the vegetable crops must be considered. In using the word vegetable, in this case, it means anything growing in the soil, either bush, tree or vine fruits, edible vegetables, grass, grain, flowers, plants, shrubs, etc.

Animals drink many times their weight in water annually, according to N. J. McGee, Soil Water Expert of U. S. Bureau of Soils, and consume indirectly in their feed that much larger quantity required for the growth of the vegetable matter that they consume. The human consumption is still larger. A pound of bread is the equivalent of two tons of water, used by the growing grain; and a pound of beef the equivalent of fifteen to thirty tons of water consumed by the animal directly and indirectly through the feed. The adult person who eats two hundred pounds each of bread and meat in a year, consumes a ton of water in drink, the equivalent of four hundred tons of water in bread and four thousand tons in meat.

The domestic consumption of water is estimated at two hundred and forty gallons per year per capita for drink and ten times that for various personal uses and waste, and twelve times this amount for live stock.

In making calculations for irrigating, the minimum amount of water required by the crops to be grown must be considered as well as the average price received for the crops.

Where intensive cultivation is to be practiced and crops grown which necessitate a considerable outlay of money, such as florists' plants and some nursery stock, sufficient water is required, and with ample pressure, for the use of a hose, sprinklers or the overhead pipe sprinkler system, now in general use.

Sandy soils of coarse texture may require water every day or two, while once in three to six days may be sufficient for soils of finer texture. Sandy soil, with a coarse subsoil and with the water table down five feet or more below the surface, will require water more frequently than the same soil having a more compact and retentive subsoil, where the water table is higher. The character of the crop, the method of applying the water and the quantity applied will regulate the water requirements.

Soils of coarse texture with porous subsoils are the cause of large unproductive areas in New York, New Jersey, Michigan, Wisconsin and throughout the South. No doubt these soils could be made productive by proper irrigation.

Actual Results from Irrigation.—In experiments at the Wisconsin Experiment Station, conducted two succeeding years, the increase in marketable potatoes was 105.9 bushels more on fields irrigated, as the plants seemed to need it, than crops grown in the ordinary way. On cabbage the average was 3.12 tons greater per acre in favor of the irrigated field. The amount of water given was 8¼ inches in four applications, July 21, August 3 and 10, and September 3.

With strawberries the increase in the irrigated crop was 173 bushels more per acre than those not irrigated. The irrigated field produced three times as many berries and the fruit was larger and more salable

It is the general experience, in irrigating raspberries and gooseberries, that an increase in fruit many times greater than those not irrigated is the result.

Close Planting under Irrigation.—One advantage of irrigation lies partly in the fact that planting may be much closer than under ordinary cultivation.

In a small experimental vegetable garden, well fertilized, vegetables were planted as closely as they could develop and not overlap—radishes, lettuce, onions, beets, corn, etc. The seed was sown thickly and the plants kept close together in the rows and the rows close together. The plot was 60 by 60 feet. Water was supplied liberally, daily. Crop after crop was harvested and planted and the table of a family of four supplied through the season, and neighbors were frequently presented with fresh vegetables.

Where rain is abundant or irrigation practiced, the plants may be set so closely together that they have only room to develop, providing there is sufficient plant food in the soil, with sunlight and air. A small plot of large plants such as corn, may be planted closer than a large field, as air in one case will be ample and in the larger field, deficient.

The effect of water supply on crops is shown in a table on page 174 of the Year Book of the Department of Agriculture for 1910. The effect is here summarized, showing yield per acre in bushels:

Water	Corn	Oats	Wheat
1½ acre feet	10 bu.	15 bu.	6 bu.
5 acre feet	105 bu.	120 bu.	40 bu.

Ancient Greek philosophers thought water was the sole food of plants and this is not strange. As has been shown, water constitutes from sixty to ninety per cent of the green weight of plants.

Irrigation an Ancient Practice.—The practice of irrigation dates back beyond authentic history. Evidence of Egyptian irrigation canals along the Nile have been found which were in use more than 2,000 years B. C. At the present time, not more than one-tenth of the water of the Nile empties into the Mediterranean Sea, the balance being utilized through irrigation canals. One of the Assyrian canals was 400 miles long and in some the whole flow of rivers was turned and along the banks were gardens and plantations. China also has great irrigation canals. In America, in what is now New Mexico, Arizona and Colorado are found ruins of ancient towns and irrigating canals used by this early civilization.

At this point it is interesting to note that our speculations as to the possibility of the existence of people on the planet Mars are based on the observation of supposed irrigation canals which we think may carry the melting snow at the poles to fields of vegetation.

Chapter XXII

SEWAGE AND RAIN WATER

Sewage waters, not contaminated with poisonous compounds, such as the refuse of dye houses or other injurious chemicals, and not too highly concentrated, are very valuable for irrigating and fertilizing purposes. They are largely used in England and in some places on the continent.

In America, sewage is emptied into lakes and streams. In some cases unfortunately, as along the shores of the Great Lakes, water from the lakes is used in the city water supply, as at Chicago, Cleveland and other cities. In these cities, at times, if not at all times, the water is unfit for human consumption, often spreading disease, such as typhoid.

Sufficient valuable fertilizing material is wasted in sewage thus wasted to pay the cost of extracting and supplying farmers with a cheap and greatly needed fertilizer. No substantial permanent effort is now made to protect the drinking water and conserve the sewage of these cities. Cooperation of city, county, state and government legislators could very easily effect valuable reform.

If the sewage run into the rivers and lakes of this country, containing matter that pollutes the waters and endangers health, was filtered or spread over wide areas where it could deposit the solids, in a manner so the flow could be controlled and directed from one basin to another, the deposits could be gathered, and this valuable material used for fertilizing purposes.

Reclaimed sewage fertilizer would probably sell for sufficient to pay the operating costs and a profit besides. Our lakes and streams would no longer develop unhealthful atmospheric conditions, making the water unfit for use.

Plant Food from Water.—In some locations farmers do take advantage of the plant food carried in the waters of streams into which the sewage of cities is discharged. On the Edinburgh meadows, Scotland, from three to five crops of grass have been cropped for many years, with no fertilizer other than that contained in the sewage water with which it is irrigated and these lands bring a high rental.

Sewage farms in England, having good loam soil, use from 30,000 to 40,000 gallons of sewage per day, showing clearly the possibilities and desirability of using this material.

Sandy soils, when irrigated, if the water contains silt, are in time greatly improved by the deposit, which improves the condition of the soil as well as supplying fertilizing material.

Rain Water Valuable.—Hard water contains lime and therefore, where very best results are wanted, as with rhododendrons, azaleas, and other ericaceous plants, they should only be irrigated or otherwise watered with rain water.

English gardeners value rain water for watering certain plants and store up in cisterns what falls on their greenhouses and other buildings. Some florists have cisterns in their greenhouses. The temperature of the water in cold weather is raised by the heat of the greenhouse so it does not chill the plants.

Chapter XXIII

NOTES ON MOISTURE —SECOND CROPS

Roots of land plants absorb moisture from the soil and through the moisture the salts held in solution. The innumerable delicate root hairs hasten the solution of plant food in the soil, in addition to keeping up the needed supply of moisture for the support of the plant.

Transpiration Accounts for Great Water Loss.—Great quantities of water are required by plants, to replace that which is given off by the immense leaf surface. To better understand the matter, consider the surface that would be covered, if all the leaves of a fully developed fruit or shade tree were spread out, without overlapping. Consider also that this is only half the surface or less as the underside of the leaves constitute another surface. Air enters the pores of the leaves and the internal surface greatly exceeds that of the outer surface.

In one of his numerous experiments Prof. King calculated, as a result of transpiration, that an acre of corn in a period of thirteen days, when the plants were coming into tassel and forming ears, removes 244 tons of water from the soil, and this water was withdrawn through the great mass of root hairs, spread through a soil so dry that no amount of pressure could squeeze a drop from it.

Irrigation Makes Second Crops Possible.—After early summer, the surface soil in humid sections, becomes quite dry and water does not sink in readily. This makes the growing of a second crop both difficult and uncertain as illustrated by the fact that second crops of hay are raised only occasionally. The rainfall during summer and autumn is sufficient for the purpose, from figures supplied by the Weather Bureau. The trouble is that the rain water is held near the surface and does not reach the roots, as shown by the crop produced when the rainfall during this season is excessive. Where irrigation is possible a good second crop may be depended on, providing fertility is maintained.

Where irrigation is not possible, autumn plowing, recommended elsewhere, should frequently be done and as late as possible, so it will not be washed by early rains. This plan is advisable for all crops, including small fruits, in orchards, and in circumstances where there will be no danger of inducing too late growth and subsequent winter killing, if plowed just before freezing.

Subsoiling as an alternative to irrigation is done, in heavy soils, permitting the water to enter the soil to a greater depth and to be retained there ready to work up by capillary attraction as and when needed by the plant roots. With horses, subsoiling is rather a hard and expensive job, but tractors simplify the operation.

Needed Oxygen Supplied by Watering and Stirring.—Plants need oxygen in the soil for the respiration of the roots, quite the same as human beings require it in the air for the lungs. We know that the more persons there are crowded into a room, the more difficult it soon becomes to breathe; the same result is produced when plants are crowded in planting. If the soil is mellow, containing a goodly amount of organic matter, and is kept stirred and well watered, it is surprising how closely plants may be placed, when this seems necessary, and still thrive.

Oxygen in the soil decreases, however, as the quantity of surplus water increases; not only the roots of the plants are using the oxygen, but also the germs which transform humus into nitrates. Therefore, watering by irrigation or other methods must not be overdone.

Where very close planting is practiced, it is not likely to be successful unless available nitrates are applied directly to the soil in sufficient quantity, as well as potash and acid phosphate, in addition to organic matter, such as decayed leaves, manure or decayed vegetable matter of some kind. Thick, heavy growth densely shades the surface and absorbs most of the heat from the air. This reduces the temperature of the soil which slows up the work of the bacteria and they will not supply as much plant food as they would were the soil warmer. At the same time, the lowered soil temperature lessens the root pressure which is needed to send the liquid plant food up into the foliage where it is assimilated.

Starches and cellulose from which plant tissues are built cannot be organized in too poor sunlight.

Quantity of Water Required for Cultivation.—Eighteen acre inches of water has produced 60 bushels of wheat to the acre; 15 in., 70 bushels of barley; 16 in., 100 bushels of oats; 17 in., 100 bushels of corn; 6 in., 300 bushels of potatoes and may be reckoned as the least amount of water necessary. In most cases, more acre inches water will be required.

An acre inch is the amount of water required to cover one acre an inch deep. See "Measuring Water" in Chapter XXIV.

Chapter XXIV

QUANTITY OF WATER—MEASURE, TEMPERATURE

The conditions which must be considered in arriving at the amount of water needed are: the capacity of the soil and subsoil to store capillary water; the depth of soil penetration by the roots of the plants; the rate at which the soil below the roots will supply water to the roots by capillary attraction; and the amount of water in the soil or the extent to which both the soil and subsoil have become dry.

The frequency of applications of water depend on: the amount of moisture in the soil available for plants; the rate at which water is lost through consumption by the crop; by percolation or drainage; and, by evaporation. The amount of water supplied by natural rainfall should also be considered.

The object of irrigation is, as has been said, to produce the largest crops possible. Therefore water to produce this result should not be withheld. More than sufficient water supplied means unnecessarily increased labor. The less the field is wet, the less will be the amount of water lost by evaporation and seepage. Consequently the higher will be the service of the water used.

As a general rule, apply as much water as the crop will stand, where water is plentiful. Then cultivate frequently for the good of the crop. Cultivate also to reduce the frequency of applications where water must be used more sparingly.

Examples: Wheat in Colorado is irrigated twice during the season, as a general rule, sometimes three or even four times. In New Mexico, irrigation before sowing and five or six times after sowing is the general practice. In Italy, fruit trees are watered every week or two throughout the season.

Measuring Water.—Water is measured by the acre-inch, which means sufficient water to cover one acre, one inch deep. For instance, six acre inches is water sufficient to cover six acres one inch deep, two acres three inches deep or one acre six inches deep. One acre contains 43,560 square feet, and as a foot contains twelve inches, one acre inch equals one-twelfth of 43,560 or 3,630 cubic feet. In a cubic foot there are 1,728 cubic inches and 231 cubic inches in a gallon. One cubic foot equals 7.43 gallons and one acre inch equals 26,970 gallons.

Water is also measured by the second-foot which is a flow of water equal in volume to a cubic foot in one second of time. A flow equaling a volume of one second-foot would require an hour and thirty seconds to supply an acre-inch.

The miner's inch is a measure used throughout the western mining country by miners and also for irrigation. A miner's inch is the amount of water flowing through an opening one inch square in one second of time under a stated pressure. This pressure varies in different localities. In California, for instance, fifty miner's inches are considered equal to one-second foot.

Taking a general average, a cubic foot of water per second serves 117 acres. Applied once in ten days, this would cover the surface to a depth of a trifle more than two inches at each application.

Open Subsoil.—Where the subsoil is open, having small retentive capacity, judgment will be required regarding the quantity of water applied and the rate at which it should be led over the surface, to prevent waste from its rapidly falling below the point occupied by the plant roots.

Frequent cultivation, to keep an earth mulch in proper condition, greatly reduces the amount of water needed.

The richer the soil, the less the water requirements to produce maximum crops.

Water Temperature.—The nearer the water is to the natural temperature of the soil the better. If the soil temperature were reduced to 50 degrees Fahrenheit, and held there for very long, growth would be checked and the crop might suffer. Water from mountain streams, if not used in too large quantities at a time and water from wells and springs is generally safe to use. The soil in summer is warm and water at that season warms rapidly. Water from city mains is used daily in various parts of the country with good results.

Shallow rooting plants require more water than plants having deeply penetrating roots because considerable water will be lost through percolation below the root ends. On this account the water must be applied more frequently.

Soils having the coarsest and most open texture will lose the most water through percolation. The surface evaporation from the heavier soils is much greater than from light soils.

Sugar cane requires large and frequent irrigations. Rice requires so much water that it is not considered in a class with ordinary crops, and the same may be said of the culture of cranberries. In Italy over grass meadows, during seven months of the year, a continuous flow of water is kept up.

Irrigation Developing Alkali.—If it is found that constant cropping of a piece of land evaporates water and curtails drainage sufficiently to develop alkalis, more moderate quantities of water should be used thereafter. Alkalis are injurious to crops and flooding may be necessary to wash out the soil.

Alkali Water Unsuitable.—Strong alkali water is unsuitable for irrigating purposes. Water from swamp lands containing large amounts of humic acid or injurious salts may also be unsuitable. In arid climates, not only must enough water be used for irrigating the crop, but sufficient also to wash out the salts formed in the soil.

Plants on Alkali Soil.—Plants may grow sufficiently well on alkali soil to give the impression that other causes are the result of poor crops. The crop may germinate properly, but soon begin to fail in spots. This occurs in marsh soil. The failing plants will be found to have a poor root system, the roots decaying and new ones endeavoring to form.

In such soils the alkali may not remain stationary, but be washed down several feet in the soil and then, at times, collect near the surface. The remedy for this condition is, first, proper drainage and irrigation with pure water.

Chapter XXV

HOW AND WHEN TO WET THE SOIL

Wetting the Soil.—Thorough wetting of the soil requires a study of the character of the soil and subsoil. Water in an open soil such as sand sinks down rapidly. The water, to do what is expected of it, must be lead over the field in channels so close together that the soil between will be saturated quickly.

A fine soil with a heavy subsoil will permit water to flow through channels at a considerable distance apart. The close subsoil will act as a basin, holding the water which will be raised by capillary attraction as needed by the plant roots.

When soil becomes very dry before watering, the water spreads faster and sinks in more slowly and rises more slowly by capillary attraction.

Puddled Soil.—A puddled soil results when the grains of the soil are packed together in a compact mass. In puddled soils denitrification is rapid and want of air causes plant roots to suffer.

Water Before Seeding.—Irrigated fields should be watered before plowing and seeding, so the crop will be well along before being watered again. Watering immediately after seeding compacts the soil to such an extent as possibly to be injurious;

When the soil has settled naturally and becomes bound by the roots and shaded by the plants, there is less danger of injury by flooding.

Water in channels or furrows which do not overflow, spreading through the soil between the furrows, give a result that is the opposite of puddling. Therefore where cultivation is practiced to save water, this method should be used where possible.

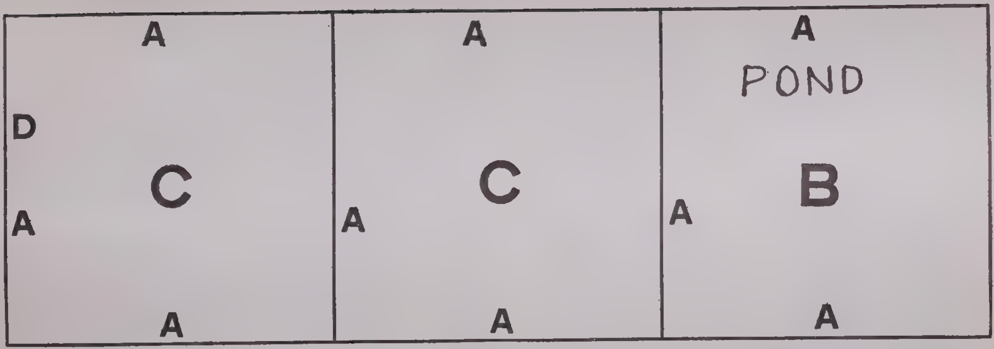
Erosion.—Be careful not to permit too rapid a flow of water as this will cause erosion or washing of the soil. Where washing results it shows that the flow is too rapid and should be lessened. On flat land where the water moves too slowly, increase the amount of water in the furrow. Where the water runs too fast it should be run into more furrows to decrease the flow.

Flooding is the most economical way of irrigating where this is possible. It also gives the most uniform results. The fields in this case are laid out in proper size with ridges surrounding the fields, to retain the water.

Each piece of land to be irrigated presents a separate problem and no general plan can be given to cover the necessities of all cases. The size of the fields enclosed must be determined by the general character of the land, its slope, the water available, etc.

Fields to be irrigated should be leveled so the water will spread evenly. Unless the field is leveled some places will receive too much and some too little water. Any form of level or road scraper will be found all that is necessary for this purpose, except in extreme cases which must be considered individually.

Furrow or Channel Irrigation.—Where crops like potatoes and corn or market garden or nursery crops are grown in rows, it may be desirable or necessary to use the furrow method of irrigation, after the crop is planted. If watering is needed before planting, the soil should be thoroughly saturated to a depth of three or four feet, before it is prepared. After planting keep thoroughly tilled. Potatoes and corn may be harrowed without injury until the plants are well up.



CRANBERRY BOG

CC, cranberry beds; B, pond; A, dikes, to retain water. The grade while small, is sufficient to let the water flow from the pond B, and flood the beds CC. The water is drained off at D

Chapter XXVI

EXAMPLES OF FURROW IRRIGATION —RICE CULTURE

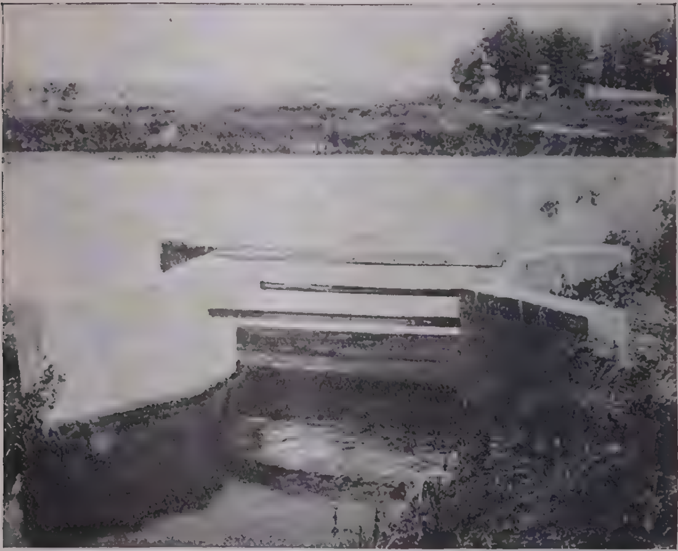
Irrigated potatoes are hilled up at the last cultivation, supplying mellow soil in which the tubers may set and over which the water should not be permitted to rise. Each row may be irrigated, or every other row.

Irrigated potatoes require a constantly moist soil after the tubers begin to form, so growth may not be checked. If the soil dries and growth is checked, the tubers will start growing when water is again supplied, which makes them unsalable.

Potatoes grown under ordinary field culture, when the tubers have formed during or immediately preceding dry weather, will sprout if left in the ground when rains are sufficient to again saturate the earth.

Cranberry Irrigation.—Cranberry bogs are located where the water is at the surface and during the growing season the water is held to within two feet or less of the surface. For special purposes it may be required to flood the bog and draw off the water quickly.

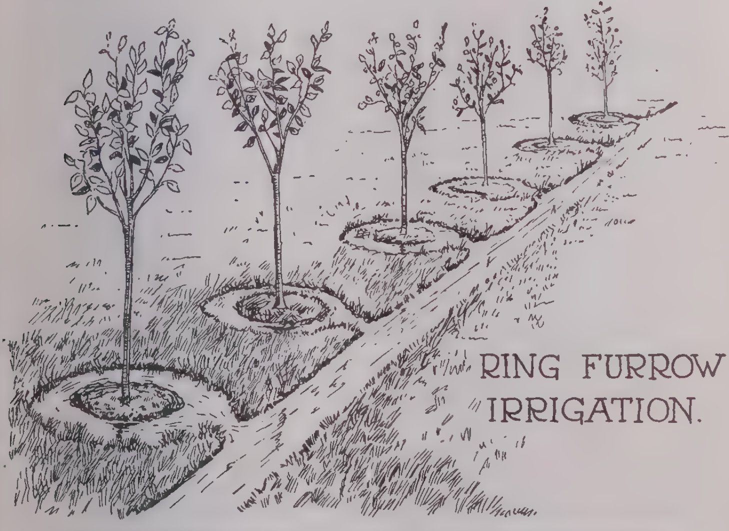
In some cranberry bogs, dykes are used to keep the water out of the beds which are lower than the water carried past them. At times the dykes are opened and the bogs flooded. The bogs are then drained by letting the water out on lower levels.



CONCRETE HEAD GATE IN A DYKE FOR CONTROLLING WATER SUPPLY

The field beyond is flooded to protect against a severe frost—U. S. D. A.

The elevation or "lay of the land" may be such as to make this system impossible on some fields. In other cases the beds are surrounded by wide ditches, topped by low dykes made from the soil removed in digging the ditches. Narrow ditches cross the beds, about twenty-five feet apart and these serve as water carriers when the water is applied and as drains when it is removed. The flooding and draining must be arranged according to the requirements of each bog. Windmills and engines are sometimes used in elevating the water.


RING FURROW IRRIGATION.

DEEP PENETRATION AT THE ROOTS IS IMPORTANT

Orchard irrigation generally is the furrow system. The water is led between the rows of trees, through the orchard in shallow furrows, in slowly flowing streams, so as to allow the water to spread widely and penetrate deeply. Deep penetration is important as the roots of matured trees, such as apples, where the earth permits, penetrate to great depth. Three or four feet of the surface should, if possible, be wet and in doing this a good lateral spread will result.

Young trees require that the soil about them be moist and until well established require ample water. This is given economically by furrows encircling the trees. As soon as the soil is in condition, after irrigation, orchards should be cultivated and this repeated frequently.

Irrigating Small Fruits. –Small fruits respond to irrigation in a manner to delight the heart of the cultivator. Irrigation increases the production and size of raspberries prodigiously and the flavor seems better. The gooseberry, a delicious fruit when ripened on the bush, is comparatively unknown in America—perhaps because it is not generally understood that the gooseberry requires a constantly moist soil.

Strawberries, blackberries and other small fruits may be grown of excellent quality and good yields in humid climates, but ample water aids them remarkably.

The irrigation of small fruits may be by the furrow method, the streams each side and close to the rows or by one of the systems of overhead irrigation.

Rice culture is possible where the field may be flooded to a depth of six inches every ten days.

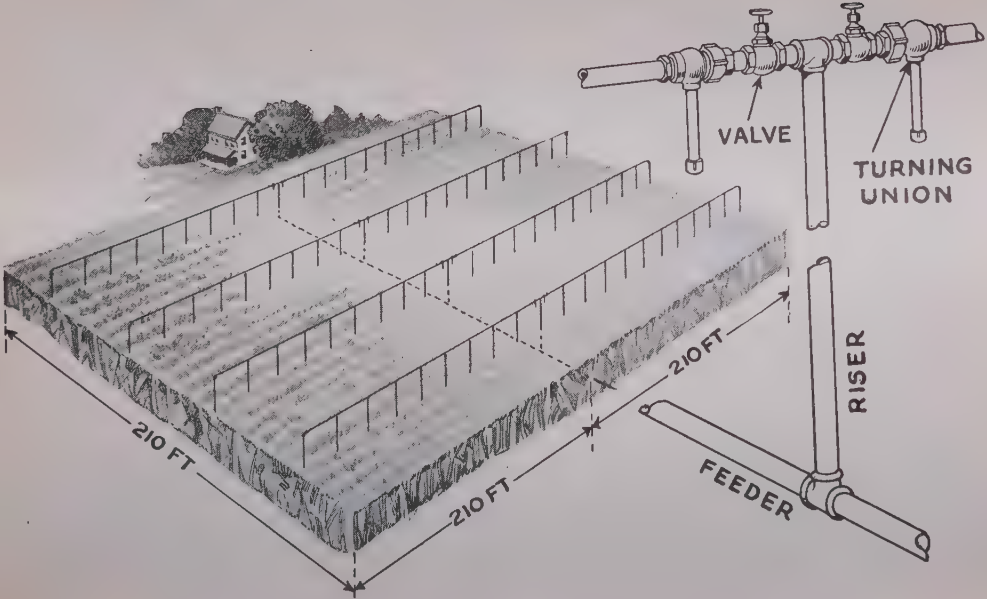
The fields are plowed and seeded in the spring and flooded six inches deep, the water held at this level until the seed has germinated and the first three roots formed. The water is removed for three days, which advances root growth. The field is then flooded to cover the plants. The water is changed each week for three weeks. Then the water is removed and the field hoed twice, the dry roots forming and the heads finally becoming ready to form. Weekly irrigation is again given and continued until the crop matures.

As the water stands it becomes stagnant and affects the plants adversely.

Care is taken to see that the fresh supply of water reaching the ditches forces out all of the old water from the fields.

Red rice lowers the grade price. This is caused by the seed ripening and falling before the crop is harvested and germinating the next season. This is controlled, after the harvest, by flooding the field, causing the seed which has fallen, to germinate so the young plants will be killed by frosts. Where this system cannot be operated, some plan must be utilized, by rotation of the crop or otherwise, to kill all the red rice in the soil, before planting another crop. The early fallen rice is said to retain its vitality for five years and may appear after three, four or even five years, unless killed.

DIAGRAM OF MARKET GARDEN WITH (White) OVERHEAD IRRIGATION SYSTEM



Showing detail of valve and turning union. Turning may be done by hand or by motor

Chapter XXVII

OVERHEAD IRRIGATION

Overhead irrigation is accomplished by lines of pipes above the heads of the workers, fitted with nipples or nozzles which throw fine streams rather high in the air, distributing the water over a wide surface. The pipe lines are run parallel, fifty feet apart. The nipples are placed three feet apart along the pipe lines, and as they throw but small streams, are permitted to run for a considerable time. The pipes turn on their supports by a lever at one end. In this way each pipe line waters a space of twenty-five feet each side of it. The water may be turned on or off of any line, as desired.

The pipe lines are set high enough so cultivating can be done under them either with horses, power or by hand. Some market gardeners set the pipe lines not more than three or four feet high.

Some overhead irrigation systems are now provided with automatic oscillators, operated by the flow of the water. These oscillators will operate a line 500 feet long on 35 pounds pressure. With this attachment the water may be turned on at night at nine o'clock and by six the next morning, the crop will have had the equivalent of an inch of rain.

A power oscillator driven by a small motor is sometimes used for units of this system covering fifteen to twenty acres oscillated in unison.

AUTOMATIC IRRIGATION SYSTEM BUILT HIGH
so that teams, tractors and farm machinery may be used without interference

An oscillating line moves from one side to the other while the water is flowing, so both sides of the line are watered at the same time.

Water for overhead irrigating systems may be supplied from a tank, elevated enough to give a good pressure in the pipes, or from the town water system when the pressure is sufficiently heavy and the cost not prohibitive.

The **roots** of bush berries penetrate deeply, so that thorough saturation may be made before the fruit is ready to pick and the water retained by thorough cultivation.

With the overhead system the water can be controlled so that it may be kept away from the part of the field where pickers are at work and the balance watered until time for the pickers to operate. Water may again be applied where the fruit was picked to encourage more flowers and ripen the green fruit.

Strawberries are so shallow rooted that irrigation may be necessary during picking. With the overhead system any part of the field can be watered or withheld from other parts, as may be desired to dry up the soil sufficiently for the pickers to work on.

With the trench system strawberry beds are laid out by some growers so the water is led between alternate rows, leaving dry rows of land to walk on.

Vegetable gardens operated by market gardeners are laid out in comparatively small beds, on light open soil and various systems of irrigation used. The overhead system is coming into quite general use for vegetables. Any system that will wet the beds quickly and economically, without washing the soil will give increased production. Where market competition is keen, vegetable growing may not be profitable without irrigation even in humid sections.

Celery and lettuce growers use a system consisting of furrows eighteen inches apart and six inches deep. This leaves a ridge eighteen inches wide between each furrow. Lettuce is planted on one side of the ridge close to the furrow and celery on the other side. At the head of the furrows, a stream of water is led and from this, one furrow is filled at a time until all the furrows have been supplied. A furrow filled once is supposed to be all the water that is needed.

A home made system of watering with lengths of hose gave good satisfaction over some twenty acres. A stream was dammed up to form a pond or reservoir as a source of supply. Wooden tanks were raised on a platform high enough above the highest point of land to give sufficient pressure to insure a rapid flow through the pipes and hose. Water was raised by a windmill. Galvanized pipe was used for the mains which were run in trenches, below the plow line and the pipes were brought to the surface at various points, fastened to 2 in. x 4 in. stakes, set securely in the ground and supplied with a faucet having a thread to which the hose could be attached, forming a hydrant. The hydrants were located so that with a hose a hundred feet long, the whole surface could be watered.

Sprinklers were used for watering, made of inch pipe five feet high. A thread cut at each end. At the bottom, a **T** was used. Below a foot of pipe was inserted and the end of the pipe heated and pounded to a solid point. A short piece of pipe, threaded inserted in the **T** to which the hose was attached and detached. The top fitted with a rose similar to the rose on a watering pot, turned at a slight angle. The sprinklers set up and allowed to run until the soil was sufficiently wet, and then moved to another location. Six or eight sprinklers were operated at a time. In the autumn the water was shut off from the pipes and what remained in the pipes was drained out to avoid damage by freezing.

The overhead system is satisfactory and considered more economical than systems where the lines are laid and the water liberated under the surface of the soil.

Sub-irrigation, that is, irrigation from below the surface, has been so generally unsatisfactory where tried, that it is sufficient to say of it, that it is not recommended.

Watering Lawns and Trees.—To reach the roots of trees and even the more shallow rooted shrubs, a supply of from two to three inches of water is required. This can not be furnished by a light sprinkling with a hose.

Lawns will do better when they are more thoroughly supplied at one time with water and less frequently, rather than continuously watered so lightly that only the surface is wet.

Light watering results in the roots seeking the moist surface soil, thus growing closely to the surface. In hot weather the moisture quickly dries and the hot sun and winds cause the grass to dry up.

Deep wetting leads to deep rooting and deep rooted grass plots have a better opportunity than shallow rooted and will stand more drought.

More effective watering can be done for lawns, trees and shrubs by laying the end of the hose on the lawn and permitting the water to flow with only such force as will allow it to flood the lawn without washing. When one space is well flooded, draw the hose to an adjoining space, and so on until the whole surface has been well covered. If a sprinkler is used, allow it to remain in one place until the soil is wet two or three inches deep.

Trees in our public parks die constantly, and quite generally because they do not receive sufficient water.

Domestic water systems, operated by electric or gasoline motors, are now to be had suitable for suburban homes, supplying water from wells or springs for house, barn, garage, lawns and garden.

AERATING PLANT ROCHESTER, N. Y. SEWAGE DISPOSAL SYSTEM

Chapter XXVIII

SEWAGE IRRIGATION

Sewage water that is free from oil and grease is valuable for irrigating, as has been stated in a previous chapter. But the organic matter which it contains must be oxidized and rendered harmless through fermenting germs.

Light loams and sandy soils are best suited to sewage irrigation. On heavy soils, care must be exercised not to use too large quantities or to water too frequently.

In cold climates where the ground is frozen for several months every year, the sewage water can be used in crop production only during the growing season. As fermentation progresses favorably only above 50 degrees Fahrenheit, the filtration of sewage into the soil takes place, in cold weather, without purification through fermenting germs. In such cases land should be reserved on which no sewage has been applied during warm weather. This land being dry will retain much water which would be purified when the weather is warm and growing crops will then benefit.

It has been proved that sewage water passing slowly through the soil where there is plenty of air, subject to denitrification, is perfectly pure. Not more than two inches of water should cover the land and be allowed to sink in. This becomes purified and as it drains away, the land is covered again. The former covering being purified, draws in air as it sinks and the operation is repeated. If water is applied before the previous covering has been completely purified, the water may be dangerous.

Examples:—Just outside of Paris, on what was once worthless and unproductive land, a garden is maintained, to show

how the sewage water should be used. The growth in the garden is luxuriant and the surplus water that flows away into the Seine is so pure that housewives take it away in pails for home use and the workmen use it for drinking water. Lands in this locality, once so poor that nothing grew on them, are now rented to market gardeners at a high rental. The sewage is carried in underground pipes and released through hydrants.

Through the south this system could be operated the year around, the immense fertilizer bill of that section greatly reduced, and at the same time the health of the people would be improved. The land in southern New Jersey and States below it could be continuously operated in this way.

Rochester, N. Y., reduces its garbage in a plant free from nuisance, so it can be conveniently located in the city. About 450 lbs. of tankage is recovered and from 60 to 85 lbs. of grease, per ton of garbage. Tankage is used for feeding hogs and other animals and is also a valuable fertilizer.

The rubbish incinerating plant, located nearby, furnishes the steam used on the garbage reduction plant. The fuel is largely refuse wood, strawboard boxes and other collected rubbish. All the material is sorted and tin cans and tops are the only waste. Glass, white and yellow metal, rubber, rags and paper are sold and the plant is nearly self-supporting.

The sludge from the sewage disposal plants in Rochester is sold to farmers, market gardeners and fruit growers for fertilizing purposes. It contains about fifty per cent moisture and two per cent nitrogen when dry. It is sold, when dumped into the farmers' vehicles, at seventy-five cents a load, regardless of the capacity of the truck. Farmers from as far distant as seven or eight miles call for it and use it as a fertilizer and as a top dressing for orchards. This price only a little more than pays the city the cost of handling the sludge.

Chapter XXIX

FERTILIZERS—INTRODUCTORY NOTES AND TABLES

Scientifically, there is a difference between the terms "fertilizer" and "plant food," but, generally speaking, these terms are applied to any material that directly or indirectly encourages plant growth and are so used in this work.

Some fertilizers, or plant foods, are immediately available, like nitrate nitrogen. Others are available, but somewhat slower in action, like ammonia. Other fertilizers, like green crops turned under, are indirect fertilizers and are much slower in becoming available. Lime used to neutralize acidity is another illustration of indirect fertilization. The average person has not the time to go minutely into the scientific details.

Available Plant Food is plant food or a constituent in such form that plants can utilize it at once.

The use of fertilizers in however large quantities will not take the place of good tillage. Good drainage, lime as needed, tillage, and properly balanced fertilization are the bases of good crops.

Organic Matter.—The maintenance of a proper supply of organic matter in the soil as a fertilizer is of first importance, as productivity depends largely on the humus content of the soil.

Organic matter in the soil may be increased by plowing under green crops of rye, clover, buckwheat, peas, beans, vetch, etc., when they have reached their maximum growth.

Barnyard manure was formerly depended on for the soil supply of organic matter, but it is becoming scarce and other materials are used in its place. Leaves that fall from the trees in autumn are valuable and should be saved for this purpose. Straw is good and peat also may be useful.

Inorganic matter applied to the soil assists the soil to regain its natural and fertile condition. Applications of various chemicals to the soil is a complicated and absorbing study that needs the attention of every gardener and grower.

Applications of organic and inorganic matters to the soil for the purpose of fertilizing it and supplying plant food is covered in the following chapters.

Composition of the Soil.—To understand the reason for application of fertilizers let us look at a table that shows us the average chemical composition of good soil. We find:

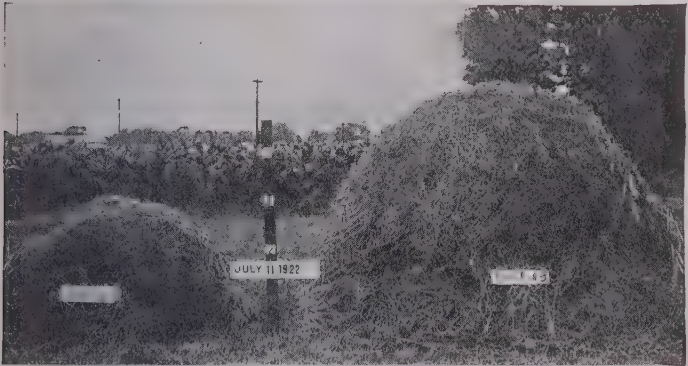
	Per Cent		Per Cent
Oxygen	47.0	Magnesium	2.6
Silicon	28.1	Sodium	2.6
Aluminum	8.2	Potassium	2.3
Iron	4.6	Sulphur, phosphorus, etc.	1.1
Calcium	3.5		

Oxygen, silicon and aluminum make up more than 83 per cent of the constituents of the soil, but contribute no plant nourishment.

Mineral Compounds in the Soil.—Portions of rocks converted into soil undergo definite chemical changes. The following chemical compounds are also generally present to a varying extent in soils. They are the **inorganic** soil constituents:

Calcium
As carbonate, nitrate, sulphate, silicate, phosphate.
Potassium
As carbonate, nitrate, sulphate, silicate, phosphate, chloride.
Sodium
As carbonate, nitrate, sulphate, silicate, phosphate, chloride.
Magnesium
As carbonate, nitrate, sulphate, silicate, phosphate, chloride.
Iron
As oxide, hydroxide, hydrated oxides, phosphate, silicate.
Aluminum
As oxide, hydroxide, hydrated oxides, phosphate, silicate.
Manganese
As oxide, hydroxide, hydrated oxides, phosphate, silicate.

Not all of the above inorganic constituents of the soil, such as oxide, hydroxide, hydrated oxides, phosphate, silicate, are, however, important to growing crops.



STRIKING EXAMPLE OF VALUE OF FERTILIZER
Pile at left:—no fertilizer for fifteen years. Yield of timothy hay, ¼ ton to the acre
Pile at right:—from land receiving manure and commercial fertilizer regularly. Yield of timothy hay, 2¼ tons to the acre. N. Y. State Exp. Sta.

The following table gives the amount of fertilizer advised per acre, what the amount will be per square foot and the approximate amount for ten square feet:

Table for Applying Fertilizer.

Amount per Acre in Pounds	Equivalent per Square Foot in Ounces	Equivalent per Ten Square Feet in Ounces
100	.036+	⅓
200	.073+	¾
300	.110+	1 1/10
400	.147−	1½
500	.183+	1⅘
600	.220+	2⅕
700	.257+	2½
800	.294−	3
900	.330+	3⅓
1,000	.367+	3⅔
1,100	.404+	4
1,200	.441−	4 2/5
1,300	.478−	4¾
1,400	.514+	5 1/7
1,500	.551−	5½
1,600	.558−	5 9/10
1,700	.625−	6¼
1,800	.661+	6⅗
1,900	.698−	7
2,000	.735	7⅓

To find the quantity of fertilizer per square foot, when a given amount of fertilizer is recommended in tons or in pounds per acre, there being 2,000 pounds in a ton, multiply the number of pounds per acre by 16, the number of ounces in a pound and divide the result by 43,560, the number of square feet in an acre. Knowing the amount in ounces required for each square foot, the quantity for any area may be obtained by multiplying the number of square feet in the area to be fertilized by the quantity required for each square foot.

Why Fertilizers are Necessary.—Edward J. Russell, international agricultural expert, comments on American farming as follows:

ABANDONED FARM
Exhausted soil is now being reclaimed through use of commercial fertilizers and green manure

"The crowding of population into cities, and the cheapening of transportation rates, led to the adoption of what is perhaps the most wasteful method of farming known: continuous cropping without spells of leguminous and grass crops. The organic matter was rapidly oxidized away, leaching and erosion increased considerably when the cover of vegetation was removed; while the compound particles that had slowly been forming through the ages soon broke down. Nothing was returned to the soil, the grain and other portable crops were sold and the straw burnt. The result has been a rate of exhaustion unparalleled in older countries, and beyond the farmer's knowledge to remedy, so he left the land and moved on. The experiment of Hopkins at Illinois and Whitson at Wisconsin, have shown that additions of lime, phosphates and potassium with the introduction of rotations including grass and leguminous crops and proper cultivation will bring about a marked improvement."

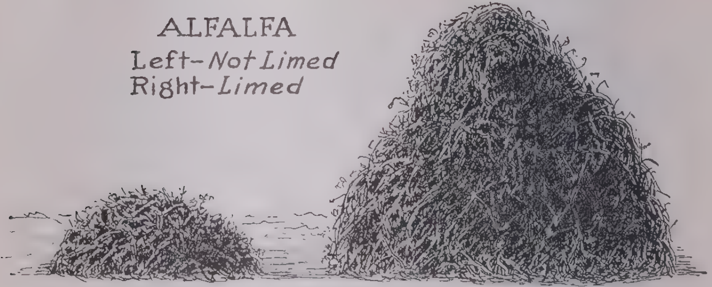
For handy reference, at the beginning of our study of the subject of fertilizers the following table is given. Material will analyze differently from different parts of a pile, or material from different localities. Therefore the analyses in the various tables may be slightly different.

Fertilizing Constituents in 100 Pounds of Various Matter

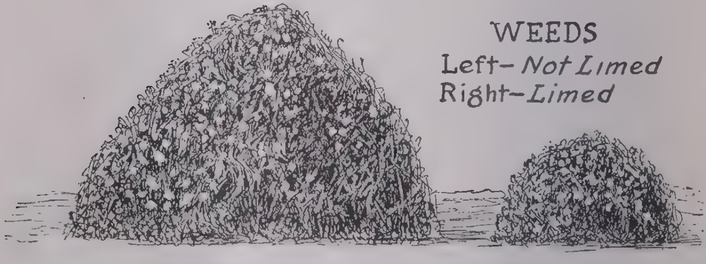
	Nitrogen	Phosphoric Acid (P_2O_5)	Potash (K_2O)
Acid phosphate	.....	15.20	.....
Alfalfa, green	.62	.15	.35
Alfalfa, hay	1.76	.61	1.79
Ammonium sulphate	20.50	.....	.....
Apples	.05	.02	.11
Apple pomace	.17	.01	.03
Ashes, average	.....	1.53	5.13
Ash of evergreen trees	.....	2.50	6.00
Ash of hardwood trees	.....	3.50	10.00
Ashes, leached	.....	1.51	1.27
Barley	1.39	.79	.48
Barley straw	1.31	.03	2.09
Beans	4.08	1.21	1.29
Bean straw	1.14	.21	1.84
Beet, mangel	.19	.09	.38
Beet, sugar	.17	.08	.37
Blood, dried	13.50	1.35	.77
Bone meal	2.30	17.60	.01
Brewers' grains, dry	2.51	1.61	.20
Brewers' grains, wet	.62	.42	.05
Buckwheat	1.23	.69	.30
Buckwheat bran	1.18	.42	1.27
Buckwheat middlings	3.52	1.23	1.14
Cabbage	.28	.22	.52
Carrots	.12	.09	.26
Clover (red), green	.46	.15	.48
Clover hay	1.08	.55	1.87
Corn, grain	1.26	.57	.37

Fertilizing Constituents in 100 Pounds of Various Matter

	Nitrogen	Phosphoric Acid (P_2O_5)	Potash (K_2O)
Corn fodder, with ears	.40	.29	1.40
Corn fodder, green, with ears	.16	.11	.39
Corn stover	.27	.38	1.64
Corn silage	.14	.11	.37
Corn cobs	.37	.04	.43
Cotton, lint	.28	.07	.64
Cotton, seed	3.07	1.02	1.16
Cottonseed meal	5.95	3.04	1.58
Gluten meal	4.12	.33	.05
Guano, Peruvian	7.00	14.00	3.30
Hominy feed	1.20	.98	.49
Kainit	.....	.....	12.80
Linseed meal	4.68	1.66	1.37
Malt sprouts	2.97	1.74	1.99
Milk, cows'	.53	.19	.18
Milk, skimmed	.56	.20	.19
Mixed hay	.99	.41	1.32
Nitrate of potash	13.09	.....	45.19
Nitrate of soda	15.7	.....	.....
Oat, grain	1.47	.69	.48
Oat straw	.19	.28	1.77
Peas	2.68	.84	1.01
Pea-vine straw	.68	.35	1.02
Potatoes	.14	.16	.57
Potassium, muriate of, 80 per cent	.....	.....	52.70
Potassium, sulphate of, 90 per cent	.....	.....	49.90
Pumpkin	.11	.16	.09
Rice	1.08	.18	.09
Rice hulls	.58	.17	.14
Rice bran	.71	.29	.24
Rice polish	1.97	2.67	.71
Rye	1.58	.86	.58
Rye straw	.46	.28	.79
Rye bran	1.84	2.28	1.40
Soy-bean	5.30	1.87	1.90
Soy-bean straw	1.41	.33	.77
Timothy hay	.44	.50	1.41
Tobacco stems	1.64	.92	2.82
Turnips	.18	.10	.39
Wheat	1.63	.87	.55
Wheat bran	1.95	2.69	1.52
Wheat middlings	2.04	1.35	.74
Wheat straw	.06	.22	.63



LIME (CALCIUM) IS ONE OF THE MOST IMPORTANT INORGANIC CHEMICAL COMPOUNDS OF THE SOIL



INFLUENCES GROWTH THROUGH ITS EFFECT ON THE SOIL AS WELL AS BY ITS USE BY PLANTS

Chapter XXX

CALCIUM (LIME)—AN INDIRECT FERTILIZER

Calcium (Lime) is an indirect fertilizer influencing growth through its effect on the soil as well as through its use by plants.

Calcium is one of the most important inorganic chemical compounds of the soil. The most important calcium compound is the carbonate ($CaCO_3$). Calcium is present also as nitrate, phosphate, sulphate and silicates. The carbonate of calcium is the commonly available form.

Calcium carbonate is present in most soils ranging from perhaps 1 per cent to 40 per cent in some limestone soils. Generally, soils which contain less than 1 per cent will not raise good crops.

Soils high in organic matter, such as muck and peat, are generally deficient in calcium carbonate, and so also are sand and clay soils.

Some of the compounds of calcium are carbonate, oxide, hydroxide, phosphate, nitrate and sulphate.

Calcium carbonate, $CaCO_3$ is known as carbonate of lime. Ground limestone contains 40 per cent of calcium which is equivalent to 56 per cent of lime (CaO). The carbonate is the chief constituent of limestone, marble, shell-marl, shells, etc. Calcium carbonate is only slightly soluble in pure water. One of its important properties is in neutralizing acids.

VALUE OF LIME ILLUSTRATED—CORN PLOT UNLIMED
N. J. State Exp. Sta.

Calcium oxide, CaO, known as quicklime, burnt lime, caustic lime, stone-lime, lump-lime, building lime, etc., contains 71.4 per cent of calcium. It is made by burning calcium carbonate.

Calcium carbide waste consists largely of calcium carbonate and hydrated or slaked lime. It can be used in liming soils, but should be exposed to the air for some weeks to permit all the acetylene gas to escape, before applying to the soil.

Calcium hydroxide, CaH_2O_2, known as slaked lime, hydrated lime, etc., contains 54 per cent calcium which is equal to 75 per cent calcium oxide or quick-lime and is practically quick-lime diluted with about one-third of its weight of water, which is chemically combined in the lime which appears to be dry.

VALUE OF LIME ILLUSTRATED—CORN PLOT LIMED

One bushel of quick-lime of good quality, on slaking, increases in bulk to two or three bushels of slaked lime, the weight per bushel decreasing about half.

When quick-lime, or stone lime as it is also called, is exposed to the air, it gradually absorbs moisture from the air and slakes, forming a powder.

Action of Calcium in Soils.—Calcium compounds must be applied judiciously to improve the soil. In too large quantities their use may be injurious. Ground lime stone is the safest form in which to use lime, particularly if it is to be carelessly applied.

Calcium compounds make available the insoluble plant-food compounds containing potassium or phosphorous. They also change the form of compounds that are detrimental to plant growth. This is particularly noticeable in crops requiring large amounts of potassium such as clover.

Calcium compounds change insoluble phosphates into forms that can be more readily utilized by plants, particularly in soils rich in iron and aluminum compounds.

Acid or "sour" soils are corrected by applications of calcium compounds such as slaked lime, quick-lime, or carbonate, but not by sulphate, which is known as gypsum or land plaster.

Black alkali soils containing sodium carbonate are benefited by applications of calcium sulphate (land plaster), which changes the sodium carbonate into harmless calcium carbonate and sulphate of soda, less poisonous to plant than sodium carbonate.

Calcium compounds in the soil increase the decomposition of organic matter in the soil, making it more quickly available for plant food. Too large or too frequent applications will cause decomposition of organic matter faster than it can be used by the plants, resulting in loss from leaching. This danger is greatest on sandy soils.

Calcium compounds, particularly the hydroxide and carbonate are favorable to important soil organisms which do not thrive in the presence of acid.

Calcium compounds are a preventive of the disease known as club-root or finger-and-toe disease in cabbage, turnips, etc., which occurs in acid soils.

Loss of Calcium.—Calcium carbonate is constantly carried away by soil water; it is removed by crops and occasional addition must be applied to keep up soil fertility.

Acids are formed by decaying vegetable matter in the soil and the soil becomes "sour" unless it contains sufficient calcium. Calcium also changes the insoluble aluminum and iron phosphates into available tri-calcium phosphates. Phosphate may be unavailable temporarily in soils lacking calcium.

Slaking Lime.—Lump-lime is usually slaked in piles on the field. About four gallons of water to each bushel of lime is slowly poured on each heap and the lime covered with fine earth.

Twenty pound piles placed twenty feet apart make about one ton to the acre. Figuring in bushels, twenty-five heaps of quicklime of one bushel each, make about one ton.

When spread, slaked lime should not be allowed to lie upon the surface over night, but be promptly worked in. Otherwise it will form lumps.

Air slaked lime or hydrated lime is in a finely divided condition and does not produce injurious action on organic matter as does caustic lime, but caustic lime, on clay soil, will have a stronger effect in granulation of the soil.

From one to two tons to the acre about every five years is all that most soils require and some not that. For light sandy soils, five hundred pounds, or a little more, will probably be sufficient.

Ground limestone is slower in its action than any of the preceding forms. It should be ground sufficiently fine to pass through a sieve having fifty meshes to the inch. It causes less destruction to organic matter in the soil than lime in any form.

Two tons to the acre every three or four years generally is all that will be required.

To supply the amount of calcium contained in 100 pounds of pure lime (CaO) requires 130 pounds of slaked lime, 180 pounds of carbonate or 310 pounds of gypsum.

To supply the amount of calcium contained in one ton (2,000 pounds) of pure lime requires 2,600 pounds of slaked lime, 3,600 pounds of carbonate or 6,200 pounds of gypsum.

Applying Calcium (Lime).—In applying lime, distribute it evenly and work it in, mixing as thoroughly as possible with the top three or four inches of the soil. Lime spreaders are made which do the work well and economically.

Lime should be purchased only by weight, never by the bushel. The weight of a bushel may vary from 60 to 120 pounds.

Amount of and Frequency of Application of Calcium.—On poor soils or light, dry soils the amount of calcium compounds used should be relatively small, about 500 to 1,500 lbs. of quicklime per acre. This is equal to 700 to 2,000 lbs. slaked lime or 900 to 2,700 lbs. carbonate.

On heavy clay soils—soils containing large amounts of organic matter, applications may be made, varying from 1,000 to 4,000 lbs. of quicklime per acre, or 1,300 to 5,000 lbs. slaked lime or 1,800 to 7,000 lbs. carbonate. But less usually is sufficient. See under Slaking Lime in previous paragraph.

One liming should be sufficient for five years. Keep the soil supplied with vegetable matter in the meantime.

Time for Application of Lime.—Autumn is the best time to apply caustic lime, such as quicklime or slaked lime, on land to be used for spring crops or on grass land. Applied before seeding, the crop may be injured. Calcium carbonate can be used any time. If caustic lime is used in the spring, work it in thoroughly.

Use caustic lime at least three weeks before stable manure or fertilizers containing ammonia and a longer time should elapse on light sandy soils.

Calcium sulphate, gypsum or land plaster may be used with manure, but none of the other calcium compounds—that is, not immediately with the manure, preferably the applications of lime several weeks in advance of applying the manure.

Calcium sulphate, calcium nitrate, calcium phosphate (known as land plaster), gypsum and sulphate of lime contain about 29 per cent calcium.

Land plaster does not correct soil acidity as does lime. It serves to supply sulphur to the soil in a harmless form. It is applied at the rate of three or four hundred pounds to the acre. It is not a substitute for lime and is not now generally used.

Notes on Application of Lime.—The rapid formation of nitrates may exceed the ability of crops to use them, if too heavy applications of lime are made. The nitrates will, in such cases, be lost in drainage. Too much lime will cause the suspension of activities of nitrifying and decay bacteria, for a time.

Calcium compounds used in sufficient quantity to make a soil "sweet" or neutral, encourage the disease known as potato-scab.

Some crops, such as watermelon, cranberry, radish, blackberry, raspberry, blueberry, rhododendrons, azaleas, kalmias, etc., produce best results on acid soils and are unfavorably affected by calcium compounds.

The extensive use of land plaster may result in making the soil acid.

Sandy and gravelly soils are made too open by the too liberal use of calcium compounds.

Muck or peat soils are injured by a surface layer of calcium. Work it in deeply, mixing well in these soils.

Iron phosphate, $FePO_4$ and aluminum phosphate, $AlPO_4$ are insoluble in water. Iron or aluminum compounds, such as oxides, present in the soil in large amounts, act upon soluble calcium phosphate that may be applied, converting it into insoluble phosphate of iron or aluminum, causing the loss of the soluble phosphate for use by the present crop. This can be prevented by keeping the soil well limed. The calcium carbonate changes the insoluble phosphates into tri-calcium phosphate, which is more readily available.

Chapter XXXI

NITROGEN

Nitrogen is present in atmospheric nitrogen, in the ammonia of animal and vegetable matter and in nitrate. About four-fifths of the air is nitrogen.

Ammonia contains fourteen parts by weight of nitrogen, combined with three parts by weight of hydrogen. Ammonia is produced when vegetable or animal matter undergoes decomposition.

Some plants utilize nitrogen from ammonium compounds in the soil, but usually the nitrogen of ammonia is changed into the form of nitrate in the soil, before plants can utilize it.

Nitrogen is one of the elements of the soil most largely used by growing crops.

Nitrogen compounds form an important part of the protoplasm of plants—the living part of plant cells. Therefore no other element so quickly benefits plant growth when properly used. The effect of nitrogen is quickly shown in the increased growth of and color of the foliage—floriferousness—more intense color of fruit, health of plants, etc. In cereals it increases the plumpness of the grain, but it will be lighter in weight than grain produced with less nitrogen.

As leaves are an important working, breathing, digesting part of the plant, the importance of good leaf growth can be understood. In many crops, such as grasses, clovers, cabbage, lettuce, etc., the leaves themselves constitute the crop. Nitrogen encourages leaf growth.

Too much nitrogen will cause plants to run to stem and foliage, instead of flowers and fruit, and to become soft and watery. On tomatoes it should be used lightly just after flowering, when the fruit has first formed.

Nitrogen Must Be Used Cautiously.—Nitrogen delays maturity and if applied in too large quantities or too late in the season to some plants, such as fruit trees, may encourage growth at a season when the plants should be hardening their wood. Unseasonable growth causes damage from frost and causes the trees to winter badly. Nitrogen increases the proportion of straw to grain, but too much nitrogen weakens the straw, causing the grain to lodge badly. It may lessen the shipping quality of fruits and vegetables.

Crops in which tenderness and crispness is desirable, such as asparagus, celery, lettuce, etc.,—this result can be obtained by the liberal use of nitrogen.

Crops that are to be stored and kept for future use should have less nitrogen than those for immediate use. Excessive use of nitrogen makes plants less resistant to attacks of insects and disease.

The effect of nitrogen in increasing the foliage of plants is to increase the amount of other plant-foods such as potassium and phosphorus that plants can use. This fact should be considered in purchasing or using fertilizing material.

Lack of nitrogen causes a stunted, sickly plant growth.

Drainage water removes nitrogen, on an average, from cultivated soils, of twenty-five to fifty pounds or more per acre annually. Crops remove about an equal quantity, so the necessity of keeping the soil supplied with nitrates is plain.

When to Use Nitrogen.—Where the soil is in good physical condition and the crop has plenty of sunshine and rain, but not excessive rains, but the plant leaves or stems are pale in color and the growth weak, it is an indication of a want of nitrogen. Excessive rains and wet soil may wash out the nitrogen and delay nitrification, causing the same effect. Disease or insects also may be the cause of the difficulty or dry weather may make it impossible for the plants to obtain sufficient food. An application of sodium nitrate in these cases will quickly produce a decided improvement in the plants.

Unusually low growth of plants, light green color of foliage or stem and soil occupied by daisies and sorrel indicates lack of nitrogen.

Often where plants are in good condition and growing well, more nitrogen may possibly be used to advantage.

An excess of nitrogen, as previously stated, may cause a too abundant and rapid growth of leaves and stalks at the sacrifice of bud, flower and fruit; the large growth of straw and small yield of grain, an overgrowth of tops with few and small tubers or roots on crops such as potatoes, turnips, etc. Celery, lettuce, asparagus, etc., on the other hand, rarely have too much nitrogen.

Average Number of Pounds of Nitrogen in a Ton of Various Fertilizing Material

Stable Manure	10
Bone, raw	60 to 80
Tankage, general range	80 to 200
Fish, dried and ground	120 to 180
Blood, dried, black	120 to 240
Cottonseed meal	140 to 160
Tankage, concentrated	200 to 240
Hoofs and horns	200 to 300
Meat scraps	260 to 280
Blood, dried, red	260 to 300
Nitrate of Soda	300 to 320
Calcium Nitrate	320
Sulphate of Ammonia	400
Leunasalpeter	520
Urea BASF	920

Chapter XXXII

NITROGEN SOURCES —PHOSPHATES

Nitrate nitrogen is offered commercially as sodium nitrate or nitrate of soda, lime or calcium nitrate, potassium nitrate, urea, leunasalpeter, etc. These are soluble in water and the nitrogen is used by plants immediately. Owing to its solubility, rain water washes nitrates down into the soil below the plant roots, and in some cases removes it entirely in the drainage water. Nitrates should therefore be applied in small quantities during the growing season, to prevent waste.

Sodium Nitrate.—Nitrate of soda is one of the principal sources of inorganic nitrogen of commercial fertilizers. The crude salts are found in northern Chili and are purified by crystallization. It contains about 96 per cent sodium nitrate, or about 16 per cent of nitrogen.

Sodium nitrate, calcium nitrate, and urea act quickly and are largely used on this account by market gardeners and where a rapid growth is desired. They are the most active forms of nitrogen.

A light dressing on meadowland or lawns, in early spring, will greatly assist growth.

Continued use or too abundant use of sodium nitrate may compact and injure the soil structure.

Ammonium Compounds.—Ammonium sulphate is readily soluble in water. Some plants use ammonia nitrogen directly.

Ammonia nitrogen is quickly changed in the soil to nitrate. Its action is slower but lasts longer than nitrate nitrogen and is used where it is desired to extend the effect over a longer period. It is not so quickly removed from the soil by drainage as is sodium nitrate, as ammonium salts are absorbed by the soil, while nitrate is not absorbed in large quantities. Ammonium sulphate contains about twenty per cent of nitrogen and therefore has from sixty to eighty pounds more nitrogen to the ton than sodium nitrate.

Liberal and continued use of ammonium sulphate has a tendency to produce acid or to make soils sour. Lime is used to correct this condition.

Ammonium sulphate, like sodium nitrate should be applied where the crop is growing and not when the land is to remain idle.

Ammonium nitrate is too high in price for general use as a fertilizer. It is rich in available nitrogen, containing about thirty per cent of nitrogen.

Potassium nitrate is another form of fertilizer, too costly for general use, but valuable for special purposes, at times for use by florists or greenhouse crops. It contains 13 per cent of nitrogen and 36.5 per cent potassium, equal to 44 per cent potash.

Calcium nitrate or lime-nitrate is prepared from atmospheric nitrogen. Calcium is combined with nitric acid, containing about 12 to 14 per cent of nitrogen. The bulk of this material now in the market comes from Germany.

Cyanamid.—Cyanamid is a trade name. The chemical compound is cyanamide. It is made from atmospheric nitrogen combined with calcium. Calcium cyanamide must be decomposed in the soil before its nitrogen changes into ammonia, which in turn changes into nitrate before it can become available for plant food.

This fertilizer is a black, granulated material, with quite an odor. In wet or acid soils injurious products are likely to be formed by the use of cyanamid and it does not seem suitable for sandy soils. When used, it should be incorporated with the soil, a week before planting.

Up to the present time cyanamid has not given generally satisfactory results as a fertilizer.

Cyanamid is slower in action than ammonium sulphate, which is slower than nitrate nitrogen.

It is claimed that under some conditions, calcium cyanamid forms dicyanamid in the soil, which has a poisonous effect on plants.

Organic nitrogen includes vegetable and animal material. These must undergo bacterial decomposition, changing the organic nitrogen into ammonia, which in turn is changed into nitrate nitrogen. Urea, an air nitrate, is classed as organic nitrogen.

Commercial organic nitrogen may be had in the form of urea, a granular salt, made from nitrogen of the air, dried blood, ground fish, cottonseed meal, tankage, bone in various forms, horn and hoof meal and various forms of so-called "humus," which is dried muck or peat. An excellent form of this material is imported from Europe and is offered as Imported Granulated Peat Moss. It seems to be partially decayed, dried moss of considerable age, finely granulated

Cottonseed-meal contains about 7 per cent nitrogen, 1.3 per cent phosphorous equal to 3 per cent phosphoric acid and

1.65 per cent potassium equal to 2 per cent of potash. If mixed with cottonseed hulls, the percentage will be lower. Cottonseed meal is also used as a cattle food.

Castor-bean pomace contains about 5.5 per cent nitrogen, 0.9 per cent phosphorous equal to 2 per cent of phosphoric acid and 0.8 per cent potassium equal to 1 per cent of potash.

Tobacco Waste, including stems, stalks and dust, vary considerably in composition and are best used when ground fine. Tobacco waste contains from 2 to 4 per cent nitrogen, 0.5 to 1 per cent phosphoric acid and 5 to 10 per cent potash.

The insecticidal value of tobacco makes it especially valuable for greenhouse crops and small fruit. Apple growers in tobacco regions use tobacco stems to advantage, as a fertilizer around apple trees.

Dried Blood is dried and ground by meat-packers. Red dried blood is considered better than black, containing about 13 per cent of nitrogen, while black averages from 6 to 10 per cent with 3 to 4 per cent of phosphoric acid.

Dried Meat is offered under the name of ammonite and other trade names. It is the soft parts of animals not suitable for food, averaging about 10 per cent of nitrogen and 1.40 per cent of phosphoric acid.

Tankage consists of animal refuse of all kinds that cannot be used for other purposes, including intestines, hair, tendons, hoofs, etc. The fat is removed and the remaining material dried and ground. The composition of tankage varies greatly and the manufacturer's guarantee, as in all fertilizing material, should be carefully considered. Usually the analysis will show 6.5 per cent nitrogen and 4 of phosphorous, equal to 9 per cent of phosphoric acid.

Fish.—Fish scraps, dried fish, ground fish, etc., averages 6 to 8 per cent nitrogen and 2.25 to 4 per cent of phosphorous, equal to 5 to 9 per cent phosphoric acid.

Hoof-meal—Horn-dust contain 10 to 15 per cent nitrogen and 0.9 per cent phosphorous, equal to 2 per cent of phosphoric acid.

Garbage-tankage varies greatly, containing from 2.5 per cent of nitrogen, phosphorous equal to 1.5 to 3 per cent, phosphoric acid 0.6 to 1.25 per cent, potassium equal to 0.7 to 1.5 per cent potash. It is low in fertilizing value and should be purchased only on a guaranteed analysis and only then when offered at what the analysis shows it to be worth.

Leather meal, wool and hair waste contain nitrogen, but have little value. They must decay before becoming available. They are practically worthless as fertilizing materials and are not recommended in any form.

Guano is principally the excrement of sea fowl. The composition varies greatly depending on the region where it is found and whether from the surface or at a depth. That from arid regions contains nitrogen, phosphorous and potassium. That from a section where it has been washed by rains, may contain only phosphorus. This plant food is immediately soluble.

Good Peruvian guano is an excellent fertilizer. It was once plentiful but seems to have become exhausted. Some fresh material comes to the market now containing 5 to 8 per cent nitrogen.

All organic fertilizers should be used before the crop is planted, with the exception of urea.

Pulverized sheep, cattle, pig and hen manure are offered commercially and their contents as shown in the table below:

Pulverized Animal Manures.

Pulverized Manure	Nitrogen Per Cent	Phosphorus Per Cent	Equal to Phosphoric Acid Per Cent	Potassium Per Cent	Equal to Potash Per Cent
Sheep manure...	2.50	0.65	1.50	1.25	1.50
Pig manure......	1.75	0.75	1.75	0.85	1.00
Cattle manure...	1.34	0.40	0.90	0.70	0.85
Poultry manure..	4.1	1.18	2.7	1.07	1.3

Availability of Fertilizer Nitrogen.—Numerous experiments have been made at different Agricultural Experiment Stations to determine the relative availability of the nitrogen in various fertilizers, using nitrate of soda as a standard, giving it a standing of 100 per cent. Here are the results, quoting the lowest and highest figures: See definition of Available Plant Food on page 196.

Availability of Fertilizer Nitrogen

	Per Cent
Nitrate of soda	100
Calcium nitrate	100
Urea	100
Sulphate of ammonia	70–90
Dried blood	64–70
Bone meal	17–60
Stable manure	45–53
Tankage	49
Horn and hoof meal	68–70
Linseed meal	69
Cottonseed meal	65
Castor pomace	65
Dried ground fish	64
Wool waste	30
Leather meal	20

Acid phosphate is the term generally applied to soluble phosphate made by treating rock-phosphate with sulphuric acid.

Most acid phosphate contains about 6 per cent of phosphorus, equal to 14 per cent of phosphoric acid, but some brands run as low as 4 to 5 per cent.

Only the analysis is to be relied upon in purchasing acid phosphate. Trade names such as soluble bone, dissolved bone and phosphate have no exact reference as to what the material contains or is made from.

Superphosphate made from bone always includes nitrogen in the guaranteed analysis. Where only phosphoric acid is given, the material is acid phosphate.

Phosphorus hastens maturity, so it is valuable in wet seasons. It increases root development, so it is valuable in dry seasons and in soils where root growth is difficult. Phosphorus decreases the ratio of straw to grain and strengthens the straw; it improves vegetables and grass and makes plants more resistant to disease. Excessive quantities, ordinarily have no bad effects. This does not mean the recommendation of excessive quantities of this or of any fertilizer.

Acid phosphate is directly absorbed by plant roots and is the source of quickly available phosphorous for agricultural purposes.

Floats, a form of insoluble phosphate is composed of finely ground phosphate rock. It should be extremely finely ground, in which condition it is used on muck soils that are quite acid, giving good results.

Basic-slag, also called Thomas' phosphate powder, is a by-product of steel from iron ores containing considerable phosphorous compounds. It is a heavy, black powder of a fineness to pass through a sieve with meshes one-hundredth of an inch in size. Most of this material is imported from England as American iron ores do not contain phosphorous enough to make a rich enough slag for fertilizing purposes. It gives good results on acid soils and particularly on wet soils.

Basic slag contains calcium, magnesium and other minerals. It is particularly valuable on peat soils and soils deficient in lime.

Chapter XXXIII

POTASH

Potash is required for starch formation in plants. It is a necessary component of chlorophyl, on which the life of plants largely depends. Chlorophyl (meaning "leaf green") is the light process, only vaguely understood by scientists, whereby leaves of plants convert crude plant foods into definite plant nourishment.

Potash produces plump and heavy seed and imparts vigor to the plant, and it has a tendency to overcome the ill effects of too much nitrogen. Excess of potash in the soil does not seem to harm crops.

Potassium is required in plant nutrition for the development of the leaves and woody parts of stems, which contain larger amounts of potassium than other portions of the plant. When deficient, the stems are weak and brittle.

Potassium compounds are necessary to enable plants to develop fleshy portions of the fruit, and to keep the plant cells turgid or swollen. They are associated with protoplasm activity.

Potassium compounds are required to enable plants to better withstand the attacks of fungous diseases.

Action on Plants.—Potash is most abundant in the young, growing parts of plants.

Potassium compounds are necessary to enable plants to produce sugar, starch, cellulose and other carbohydrates, enabling the plants to combine carbon, hydrogen and oxygen supplied by carbon dioxide and water.

Potassium is supposed also to enable plants to transfer starch from one part of the plant to another.

Starch is first formed in the leaf and is insoluble. It is changed in the plant-cells into a soluble form, so it can pass through the walls of the cells, finally being carried to fruit or seed, where it again changes into an insoluble form.

Calcium and potash are necessary to assist plants in this operation.

Potassium, like nitrate, in excessive quantities tends to prolong the season of growth and thus delays the maturing of the crop. Potassium compounds produce a favorable effect on legumes, probably by promoting the growth of bacteria by furnishing them more abundant supplies of carbohydrates.

That potassium is needed is indicated by brittleness in stalks and leaves. Unfavorable appearances in crops may be due to temporary conditions which will correct themselves, such as bad weather. Disease may be a cause, and possibly the application of a proper plant food may overcome the cause of the disease. If insects are the source of trouble, these will have to be taken care of.

Where potassium is present in sufficient amounts, fruits of fine color, texture and flavor are produced.

Sandy, gravelly, muck and peat soils are likely to require potassium and phosphorous.

The ash of plants contains more potassium than any other mineral element—averaging about one-third. Potassium is always found combined with other minerals and it is everywhere present in the soil, to some extent at least.

The Latin name for potash is kalium, for which reason K is used as the chemical symbol.

When wood or other vegetable matter is burned, potassium carbonate remains in the ash. In early times potash was obtained by "washing" wood ashes, dissolving the potassium carbonate forming lye which was largely used in making soap at home. The lye, when dried, was sold as potash, as it was recovered from pots by boiling off the water.

Potash is contained in most soils in soluble forms which include sulphate, muriate, nitrate, phosphate and carbonate, also some insoluble forms. The amount varies from 1 to 3 per cent, not much of which may be available.

The percentage of potassium given in soil analysis is generally the acid-soluble, which is the available, but only a part of the potassium content.

Good agricultural soil usually contains not less than 0.2 per cent and up to 3 per cent or more of potash. Clay soils generally contain maximum amounts, while sandy soil, muck and peat are deficient.

Alkali soils usually run very high in potassium in the forms of sulphate, muriate and carbonate.

Very little potassium is removed from the soil by drainage. Crops are what take potassium from the soil.

Potassium is offered in three forms; as potassium chloride, potassium sulphate and as kainit. Potassium chloride is injurious to some crops such as potatoes, tobacco, sugar beets and some others, the sulphate in such cases being preferable. Kainit has the same effect as potassium chloride. It contains from ten to twenty per cent potash and from twenty-five to forty-five per cent sodium chloride, also chloride and sulphate of magnesium.

Apply kainit before the crop is planted and never use it in the drills with seed.

High-grade potassium sulphate contains from forty-five to fifty per cent potash.

Potassium carbonate in its commercial form is a dry powder, easily soluble and strongly alkaline, 93 to 98 per cent pure, containing about 52 per cent of potassium, equal to 63 to 66 per cent of potash. It is largely used in growing tobacco.

Formerly the potassium carbonate used for fertilizing purposes was obtained from wood ashes.

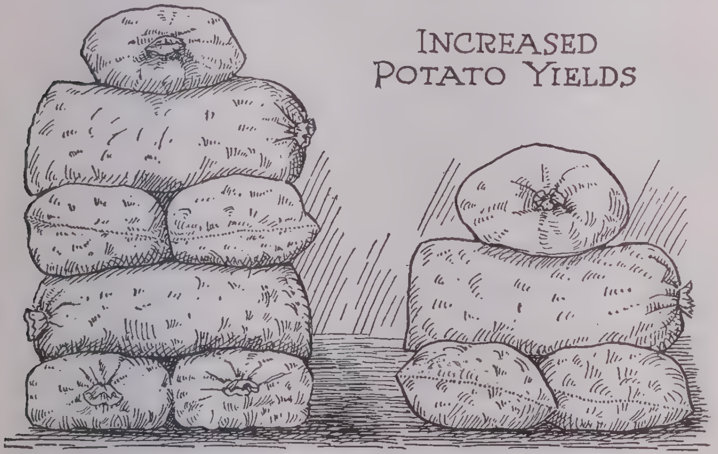
Potassium carbonate, if used in excess, will cause deflocculation, breaking up the crumb structure of the soil.

Potassium chloride is commonly called muriate of potash and is the form most generally used in mixed fertilizers. There are several grades on the market, containing as follows:

No. 1	36.5–39.3	per cent	of	potassium,	equal	to	44.0–47.0	per cent of	potash
No. 2	42.0–44.5	“	“	“	“	“	50.5–53.5	“ “	“
No. 3	47.0–50.0	“	“	“	“	“	57.0–60.0	“ “	“
No. 4	51.5	“	“	“	“	“	62.0	“ “	“

Potassium sulphate, or sulphate of potash, contains from 90 to 96 per cent of pure potassium sulphate, equal to 48.5 to 52 per cent potash.

Potassium nitrate, or nitrate of potash, niter and saltpeter, contain 38.6 per cent of potassium, equivalent to 46.6 per cent of potash. This is a particularly valuable form of fertilizer, being in the nitrate form and therefore should be applied while the crop is growing. It is coming into this country now from Norway, and when it is to be had at a reasonable price, is a very effective fertilizer for many crops, particularly valuable for florists' use.



ACID PHOSPHATE AND SULPHATE OF POTASH
Greatly increase potato yields as shown by actual results

Potash and magnesium sulphate, or double potash manure salts, contain about 40 per cent of potassium sulphate, equal to 18 per cent of potassium, or 22 per cent of potash and 30 per cent of magnesium sulphate. It is used chiefly for fruits and tobacco.

Potash Manure Salts.—This is low grade potassium chloride, averaging from 16.5 to 33 per cent potassium, equal to 20 to 40 per cent potash; it also contains common salt, sulphate and chloride of magnesium and other compounds

Potassium-magnesium carbonate contains 35 to 40 per cent of potassium carbonate, equal to about 20 to 22 per cent of potassium, or 24 to 27 per cent potash and from 24 to 27 per cent of magnesium carbonate.

Kainit, as offered commercially, contains 12.5 per cent of potash, the remainder consisting of magnesia compounds and common salt. It is produced by the German Potash Syndicate and is recommended by the producers, for crops and soils on which muriate of potash can be used. One hundred pounds per acre drilled in with corn, it is said, will keep away cutworms and root lice.

On swamps or muck land up to four hundred pounds of kainit may be used per acre, and it may be applied in the autumn without danger of leaching.

Wood ashes are obtainable, coming to this market from Canada, as unleached hard wood ashes, containing about five per cent potash, two per cent phosphoric acid and thirty per cent lime. Leached wood ashes, ashes that have been exposed to the weather, contain very much less. Purchase only under a definite guarantee.

Kelp.—The kelp of the Pacific coast, when dried, may contain as much as 275 to 300 pounds of potassium to the ton, equal to 325 to 357 pounds of potash.

Potash becomes moist when exposed to dampness and should be kept in a dry place.

SETTING PLANTS
With horse drawn machine plant setter.

Chapter XXXIV

THE FERTILIZING ACTION OF OTHER CHEMICALS

Magnesium.–The action of magnesium in plants is not very well understood, but it is known that it is indispensable. It is found in the flowers, fruits and seeds and in roots and tubers to a greater extent than calcium. Calcium exceeds it in the stems, leaves, new wood and straw. Magnesium is a constituent of chlorophyl and is associated with nitrogen compounds in the protoplasms.

Magnesium may, however, act as a poison to plants unless associated with calcium.

In chemical action magnesium and its compounds closely resemble that of calcium, though magnesium compounds are not generally used for fertilizing purposes.

Like potassium, magnesium is present in all agricultural soils in varying amounts.

Carbonate and sulphate of magnesium have been used in a limited way as indirect fertilizers. Their action is like calcium, in changing unavailable into available potassium. Kainit contains considerable magnesium phosphate.

Sulphur.—Plants contain sulphur in small amounts. Soils quite generally contain sufficient sulphur compounds to supply the needs of crops. Sulphur compounds are changed into sulphuric acid in which form plants are able to utilize them.

The compounds of sulphur include potassium sulphate, sodium sulphate, calcium sulphate, ammonium sulphate and magnesium sulphate; the percentage of sulphur in these compounds varying from 18 to 26 per cent.

Sodium sulphate or sulphate of soda is the white alkali of arid regions. In large amounts in the soil it is poisonous to plants. It is sulphur which imparts the odor to turnips, cabbage, etc.

Iron is used in very small amounts by plants. Without iron, plants develop no green color whether they have direct sunlight or not, nor can chlorophyl be formed without it and therefore no plant growth. Sometimes shoots develop so quickly that iron compounds do not reach them, resulting in white stem and leaves, often seen in geraniums grown in greenhouses or conservatories where the temperature is high with insufficient ventilation. Greenhouse workers sometimes try to propagate these white shoots by making cuttings and inserting them in a propagating bed, but they never form roots.

Agricultural soils contain all the iron needed by plants, so this element need not be considered in fertilizing operations.

Sodium occurs as sodium chloride in soils and its action is similar to chlorine. Sodium carbonate causes the black alkali in soils in arid sections, the action of the alkali on the organic matter in the soil producing the dark color. Sodium nitrate is the most important compound of sodium, for fertilizing, and its value is due to the nitrate. Sodium is of small importance as a plant food, but assists in chemical changes which take place in the soil and may aid in nitrification.

Chlorine compounds are present in practically all soils and plants. Common salt is sodium chloride and in England is used in considerable quantities on soils containing chalk—as much of the soil there does.

Salt is of doubtful use as a fertilizer. It is somewhat used to lessen the amount of potash used by root crops. In light soils it tends to hold moisture and aid capillary attraction. Kainit contains a liberal percentage of salt.

Salt must be used cautiously and experimentally before applying to any extent, or more harm than good may result. About 200 pounds to the acre is the usual application which should be given in the autumn or several weeks before any planting is done.

On clay soils, sodium chloride (salt) liberates certain plant nutrients, including calcium, magnesium, potassium and phosphorous. The structure of the soil is improved by light applications of sodium chloride as it is by lime, but not to the same extent. The movement of water from below is increased. Some crops are injured by the use of salt.

Silicon is the most abundant element in the earth's surface. It is a constituent of rocks and soils formed from rocks, both sand and clay. Silica predominates in sand. Silica is found in a number of compounds. Silicate of soda or "water-glass" is used for preserving eggs. Pure clay is hydrated aluminum silicate. Just what use plants make of silicon is in doubt at the present time.

Carbon is an important factor in all plant and animal life and is the principal element of plants.

Plants obtain needed carbon from the carbon dioxide of the air, through the leaves. The soil, however, contains also carbon and plants may obtain some carbon from the soil. When wood is heated or partially burned, the elements which compose it are driven off in the form of gases and charcoal remains. The charcoal is carbon and when heated to a higher point, also burns up, almost completely. If the wood, during the course of years, had completely decayed, it would have given off as much heat in the process of decay as though it had been set on fire and burned.

The heat given off from burning vegetable matter is equal to the heat absorbed by the plant from the sun.

The humus of soils is organic matter, partially decomposed, the carbon remaining, which gives rich soils their dark color. A soil may, however, be quite fertile and not be dark or black.

Carbon dioxide, CO_2, carbonic acid gas, contains 27.3 per cent carbon and 72.7 per cent oxygen. The breath of animals, burning of fuel, and decay all produce carbonic acid gas and as this is consumed by plants through the aid of sunlight, plants are not only not injurious but a benefit to health, when properly kept in living rooms. The carbon dioxide in soil water aids in dissolving the mineral plant food, making it available for plant use.

Oxygen forms a large part of the earth's surface, about one-half being oxygen. It forms one-fifth part of the air, all but about one-ninth part of water, one-half or more of all vegetable and one-third or more of all animal matter.

Oxygen used by plants is largely from water in the soil, though the soil also must contain free oxygen to support plant life. Seeds will not germinate in soil containing no oxygen. Oxygen is required in the soil for the support of micro-organisms and to produce chemical changes in the soil constituents.

Hydrogen constitutes about six per cent of the dry matter of plants and is a constituent of all acids. Plants and animals contain hydrogen in different organic compounds. Water contains one-ninth of its weight in hydrogen.

Plants obtain the needed supply of hydrogen from water. Within plants, water is separated into hydrogen and oxygen which are built up into compounds, according to the nature of the plant.

Organic matter is one of the most important agricultural constituents of the soil. It is not only a source of plant food, but makes available insoluble mineral plant foods and improves the physical condition of the soil.

Without sufficient organic matter in the soil, commercial fertilizers might be applied liberally without any considerable effect upon the crop. In fact, in such cases, commercial fertilizers may do more harm than good.

Muck has the effect of organic matter, making heavy clay soils lighter and more porous and binding the particles of sandy soil, increasing its water holding capacity.

When used to improve the texture of the soil, heavy applications of muck should be given, varying in weight according to the water content.

Muck is used as a filter in some commercial fertilizers. Farmers having muck available and land that may be improved by its use, should use it, applying it when there is spare time for the operation.

Chapter XXXV

GREEN CROP MANURES—INDIRECT FERTILIZERS

Green crops when plowed under, supply a large amount of organic matter to the soil at comparatively small cost. The land is kept covered by growing the green crop, which prevents erosion and loss of nitrates in the drainage water—especially in the summer months. Leguminous crops may add as much as one hundred and fifty pounds of nitrogen per acre. In addition to this, deeply penetrating roots bring up phosphorous and potassium near the surface where the green crop decomposes, so that it can be used by following crops.

Green crop manures act as cover crops, taking up soluble plant food, preventing it from being lost in leaching. Crops with long roots penetrate and open up the subsoil and bring up plant food which is deposited in the top soil when the crop is turned under, for the use of the following crop. The organic matter is added, turning into humus and aiding the beneficial and necessary bacteria, and in turn the bacteria supply increased food material for the next crop. If the green crop is a egume considerable nitrate is added.

Good drainage and proper aeration are necessary for best results from green manure.

Of the legumes, cowpea, crimson clover, red clover, white clover, alsike clover, sweet clover, alfalfa, hairy vetch, soy bean, vetch, peanut, Canada field pea and velvet beans are commonly used for green manure.

Legumes sometimes require several years to establish a good crop and where quick results are wanted, the non-legumes are the most dependable.

By sowing oats and peas, quick results will be obtained with the advantage of a partial crop of a legume.

Green crop manures, green manures and cover crops are terms used synonymously. They usually occupy the land only a part of the growing season to protect the soil and keep it covered. They are then plowed under to decay and improve the soil by adding organic matter.

For green manures, leguminous crops should be used where possible, selecting the one best suited to conditions, soil, climate, etc. Some are annuals, maturing from seed in one year; some are biennials, living two years and some are perennials, living on from year to year. Some thrive best in the warm weather of summer and others flourish in the cool weather of early spring or late autumn.

Beans, cowpeas, field peas, vetch, soy beans and peanuts are summer annuals. Hairy vetch, crimson clover are winter annuals and in the South, vetch and field peas are used as winter annuals. Crimson clover cannot be grown successfully as far north as Northern New Jersey.

Sweet clover is biennial. Red clover is also treated as a biennial.

Mammoth clover, alsike and white clover and alfalfa are perennial.

OATS SOON TO BE PLOWED UNDER FOR SOIL IMPROVEMENT
N. J. State Exp. Sta.

Clovers, including alfalfa, start slowly at first and are unsuitable where quick results are wanted. The clovers are deep rooted, penetrating the subsoil where the roots decay, opening up the subsoil so that air and water may enter, adding considerable organic matter, in addition to the nitrogen added to the upper surface.

In addition to legumes which add nitrogen to the soil, other crops which consume nitrogen are used as green manures, including rye, wheat, buckwheat, oats, barley, rape, turnip and mangels.

It is sometimes advisable to mix legumes with non-legumes to insure a better stand, including crops which grow at the same time. In Southern New Jersey, for example, sixty pounds of rye, twenty pounds of winter vetch and ten pounds of crimson clover give excellent results. In Northern New Jersey vetch and rye are used.

Caution must be exercised in green manuring in regions where the rainfall is light as available moisture needed by the succeeding crop may be exhausted in the decay of the green matter in the soil, leaving the soil light and open and the growing crop will suffer in consequence. It cannot be used in dry regions without irrigation. The vegetable matter decays slowly in dry soil and will leave air spaces, causing loss of water by evaporation.

Leguminous crops require ample supplies of calcium, phosphorous and potassium, with a little nitrate, particularly on poor soils and ample organic matter such as farm manure.

Lime is needed on land where any kind of green manures are turned under, as the decay of the plants produces acid or makes the soil "sour." The lime may be applied before the seeding or after the crop is turned under.

Plowing Under.—Green crops are usually plowed under when they have attained their maximum growth. In humid sections this will be when the rainfall is ample to hasten decay.

In any case they should be plowed under while still green and full of moisture, as they decay quickly when in this condition. Crops that become hard and dry remain in the soil a long time before decaying, drying out the soil. The result is the same when plowed under in dry soil. In the autumn, when the weather is cool, followed by autumn rains, is a good time.

TURNING UNDER A GREEN CROP
U. S. D. A.

In plowing under green crops, instead of turning the soil completely over, turn it only partly over against the next furrow. If turned completely over, the green crop will not be so thoroughly mixed with the soil. Turned completely over the mass of plants is likely to cut off capillary and it may take considerable time to overcome this condition.

If crops sown in the autumn are to be planted on land where green crops have been turned in, five or six weeks should elapse before planting, using the disk harrow frequently in the meantime and also compacting the soil with a cultipactor or in some other manner.

Some crops immediately following leguminous green manures may be affected unfavorably. The organic nitrogen in the soil may be so considerable that if moist, hot weather prevails, the nitrogen may encourage abnormal growth of stems and leaves and the yield of fruit will be decreased, the straw may be long, soft and lodge badly.

It is almost impossible in agriculture to give any exact rules. The cultivator of the soil must learn, largely from experience on the kind of soil on which he is located and in that particular climate, what is best to produce and how to produce it. Observation of what is being accomplished about him, noting the results of good farming and gardening, and poor results as well, and considering cause and effect, on which possibly improvements can be made is the safe way. Such observation is of course made much easier and of more practical and immediate value when done with a handbook such as this to guide the observer.

Indirect Fertilizers are materials which may not be used directly by plants for food, but which affect the soil favorably for plants. Lime supplies calcium which is used by plants, but its chief value is in keeping the soil neutral or "sweet," as it is called, rather than acid, also making available compounds containing phosphorous or potassium and hastening the decomposition of organic matter.

Other materials are indirect fertilizers: green crops, muck and peat, salt and even coal ashes from house heating furnaces and kitchen ranges, but they have very small direct fertilizing value. Waste material, old dahlia tubers, seeds of tomatoes, etc., thrown on an ash pile often do surprisingly well. Ashes from steam boilers are likely to be almost wholly consumed and the ash remaining being in lumps of slag that will not decompose are therefore unsuitable for agricultural use. The other ashes serve a good purpose in lightening very heavy clay soils.

PACKING THE GROUND
After turning under a green manure crop

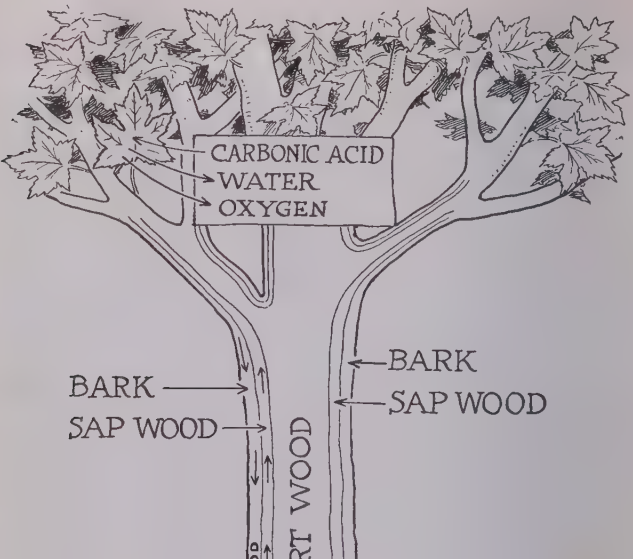
Muck or peat are valuable when at hand, but are not of sufficient value generally to be profitable when necessary to purchase and haul them. Where there is a bed of these materials on the farm, when dried, they can be mixed with stable manure which is the best way to use them.

VALUE OF GREEN MANURE ILLUSTRATED
N. J. State Exp. Sta.

Soot is used to a considerable extent in Great Britain and is imported and used by florists in America for special crops. It contains about three per cent nitrogen. It lightens heavy soils and slugs and snails, sometimes troublesome to crops, dislike it.

VALUE OF GREEN MANURE ILLUSTRATED
N. J. State Exp. Sta.

Any dark colored material such as soot, muck or peat, darkens the color of the soil. The darker the color, the more heat will be absorbed from the sun, making the soil warmer, which is desirable.



ALL THE FOODS THAT PLANTS TAKE FROM THE SOIL MUST FIRST BE DISSOLVED IN WATER

Chapter XXXVI

HOW PLANTS USE FOOD

A substance must enter a plant before it can be used as a food. Gases and liquids enter plants readily. Solids have to be dissolved in water before they can enter plants. Some compounds must be changed into other forms or combinations before they are soluble in water. Some soluble substances containing a plant-food constituent may not be used by the plant even when taken into the plant.

Water is a plant food. It is used by plants directly or decomposed into hydrogen and oxygen and is used to form other compounds, such as starch, sugar, cellulose, etc. Green plants are composed of from 60 to 95 per cent water. All the food that plants take from the soil is first dissolved in water.

Everyone is familiar with the wilted appearance of plants wanting water. Plant cells cannot be active except when well distended through an ample supply of water. Lack of water may cause an excessive fruit drop.

As elsewhere explained, water passes through growing plants in large quantities, passing into the air through the leaves. This is called transpiration. Some plants pass water into the air equal to their own weight, every twenty-four hours in dry, hot weather. A crop on an acre of land may transpire a thousand tons of water, during the growing season.

How Plants Use Food.—Plants are composed of innumerable, minute, individual cells. Roots take food from the soil and leaves take it from the air: it is conveyed to the cells where it is separated and recombined into new forms.

In the tender, growing portions of plants, the cell wall is a thin but strong membrane, through which liquids and gases pass, but no solids.

The active plant-cells contain protoplasm which is the life-giving part of the plant-cells. Protoplasm forms the different compounds that plants contain.

Air is taken in through pores in the leaves, called stomata. These pores number from 1,000 to 170,000 to the square inch on the leaves of different plants. The air containing carbon dioxide passes into the spaces surrounding the plant cells and into the cell; the carbon and oxygen are separated, the carbon used to form new compounds and most of the oxygen is passed off, through the leaves, into the air.

The utilizing of the carbon depends upon sunlight, and chlorophyl which is the green coloring matter of the leaves. The process of utilizing carbon is called assimilation.

Roots supply plant food much the same as leaves, the food constituents being dissolved in the water taken up by the root-hairs which have thin walls. New hairs are constantly forming immediately back of the growing tip, taking place of the older ones as they die off. When trees are dug for transplanting many of the root hairs are torn off. This is why trees are planted when dormant. When transplanted the root hairs have time to form again as the leaves form and call for active root support.

It is supposed that the acid solution in root hairs helps to dissolve some of the constituents of the soil, so as to be used by the plant.

The liquid food taken in by the root hairs is passed into the roots and carried through the cells to the leaves where it is made into food in combination with the carbon dioxide derived from the atmosphere. As this process can only take place in the light, it is called **photosynthesis**, meaning building up by light.

The passing of liquids or solids in solution through membranes is called **osmosis.** The passage of water from the thinner toward the denser takes place more rapidly than in the opposite direction.

If soil water contains too much soluble matter from fertilizers which renders it denser than the sap in the growing roots, the osmotic flow will be away from the plant roots and the plant may be starved by an attempt of the cultivator to feed them too liberally. The action of osmosis in withdrawing the contents from a cell is called **plasmolysis.**

When the solid matter in a soil solution is greater than 1 pound in 60 gallons of water, the plants are likely to suffer.

Water not needed is transpired into the air by the leaves. By exhaling water, the leaves keep the sap concentrated in the cells. So, also the movement of the water from the roots is kept upward by transpiration.

Keeping the soil well supplied with organic matter is one of the best ways of decreasing the amount of plant-food lost in drainage water. In addition, the soil should be well worked to keep it open so it can absorb and hold water and the crops kept growing. This is the advantage of cover crops.

Plant foods are lost, particularly on side hills, by surface washing. Furrows or ridges should be provided to prevent washing. Steep hills should be covered with grasses or trees.

Burning tracts waste nitrogen which escapes into the air and should never be practiced.

Rain-water Fertilizer.—Rain, dew and snow add from three to ten pounds of nitrogen per acre, annually to the soil in the form of nitrogen.

Supply from Subsoil.—Deep-rooted crops may bring plant-food from the subsoil to the topsoil. Thus increasing slightly the depth of plowing may be advisable. Plant food comes also from the downward fall of soil water which may afterwards ascend toward the plant roots during dry periods.

Available plant-food is plant-food or a constituent in such form that plants can utilize it at once; or a plant food or constituent that will readily become available.

Immediately available plant-foods include nitrogen as nitrate, calcium phosphate and potassium sulphate or muriate.

Unavailable plant-food is material in such form, that although it may be a plant-food, the plants cannot use it until changes take place which occur so slowly as not to furnish appreciable amounts for the present growing crops.

Delayed Availability.—Organic materials containing nitrogen such as cotton-seed meal, dried blood, etc., are not soluble in water. When mixed with the soil, bacteria aid in changing their nitrogen to nitrate nitrogen, under favorable conditions depending on fineness of material, temperature, moisture, etc. Ordinarily when such material is applied early in the spring, it becomes fully available to crops during the growing season. Stable manure is in this class, although its availability may extend over two or three years.

INOCULATING SEED

Mixing seed with an artificial culture of the proper germs to insure soil inoculation.—U. S. D. A.

Chapter XXXVII

BACTERIA'S WORK AS A FERTILIZER

Bacteria, which have been mentioned previously, are of three forms: the **ball** or coccus; the **rod** form or bacillus or bacterium; and the **cork-screw** form or spirillum.

The ball shape exist separately or in pairs and sometimes in chains or masses.

The rod-form may be short and thick or long and slender, appearing separately or several, end to end.

The cork-screw take various forms such as a quarter circle, a letter S, or coiled.

All vary more or less in form. Some have appendages like a thread which propel them.

These peculiar vegetable formations are so small that they can be seen only with a microscope, for which reason they are called micro-organisms. They require nutrition the same as higher organisms and, like them, reproduce and die.

Reproduction in bacteria is usually by division. The cells lengthen and a partition forms across the cell, making two cells where there was formerly one. Each of the new cells subdivides and so the process continues.

Some bacteria form a spore and spore-producing bacteria live under conditions which would kill other forms.

The reproduction of bacteria is marvelously rapid, in some cases reproduction taking place every half-hour.

Bacteria take food like other plants, through the cell wall and therefore only in solution.

Bacteria are numerous in fertile soil, but there are few in soil containing little or no humus or in dry soil. They are mostly located just beneath the surface, with none below six feet down.

Bacteria produce carbon dioxide, sulphuric, nitrous and nitric and organic acids which form in the soil, calcium carbonates and make soluble soil phosphates, potassium and other plant-foods, and change sulphur into sulphuric acid which forms sulphates of potassium, calcium, magnesium, etc.

Decomposition is generally considered in a broad way as covering decay. There are two forms of decomposition, that effected in air, called aerobic or decay and the other away from the air, called anaerobic or putrefaction.

When vegetable matter decomposes in air or out of air the character of the chemical changes produced by each process is different and entirely different bacteria act upon the matter. Decomposition out of the air is called humification and is slower than decay and the chemical changes do not go so far. The intermediate organic compounds formed by putrefaction are not readily decomposed by other bacteria although exposed to air. Some of the compounds formed in the putrefaction of organic matter contain sulphur and phosphorous and are poisonous.

Inoculating Legumes.—Pure cultures of micro-organisms are now offered for inoculating leguminous plants. The application is made directly to the seed before sowing. Different cultures are offered for different crops. The use of an inoculant does not in any way take the place of or do away with the necessity of properly preparing the soil for the crop to be planted, just as if no inoculant was used. Better results, however, should be obtained by the use of the inoculant.

Fungi are microscopic plants better known as moulds. They are larger than bacteria and assist in decomposing organic matter, particularly in acid soil where bacteria cannot thrive. They convert insoluble into soluble nitrogen compounds. Also they convert soluble nitrogen into the insoluble protein of which they are composed, which is again returned to the soil at their death, when they in turn undergo bacterial decomposition.

The action of fungi is seen in dry manure that is white and powdery, so much so that bacteria cannot thrive in it, a condition which should be prevented by adding moisture. Fungi cause some disease in cultivated crops.

Protozoa are much larger than bacteria. They are animals of single cells and feed upon bacteria, therefore they are a detrimental agricultural factor. They are of considerable annoyance to plant culture under glass and some florists control them by sterilizing the soil with steam or by baking. This operation kills the protozoa but only part of the bacteria and the remaining bacteria increase rapidly and quickly, thereafter flourishing without interference from the protozoa.

Slow, expensive method of applying manure.

Spreading manure from wagon—better than making piles.

Chapter XXXVIII

FARM MANURE

It is always a question as to exactly what is referred to when the term barnyard or farm manure is used. It may be the stable manure of horses or cows, mixed barnyard manure, manure from hog-pens, etc., consisting of dung, urine, bedding and also general farm waste. The manure heap, by the way, is no place for old tin cans, bottles, glass and other similar waste material.

Naturally there is great variation in manure according to the animals it is made by, the feeding and bedding material, and the manner in which it is kept. Different analyses naturally shows different results and the tables here given serve only as a guide or index to the various kinds.

Average mixed farm manure contains nitrogen, phosphoric acid, and phosphate about as follows: Nitrogen 0.5 per cent or 10 lb. in one ton; phosphoric acid 0.25 per cent or 5 lb. in one ton; potash 0.5 per cent or 10 lb. in one ton.

Fresh animal manure, excrements only, solids and liquids mixed average approximately as follows:

Chemical Content of Animal Manure

Animal	Nitrogen	Phosphoric Acid	Potash
Horse	0.70	0.25	0.55
Cow	0.60	0.15	0.45
Sheep	0.95	0.35	1.00
Pig	0.50	0.35	0.40
Hen	1.00	0.80	0.40

The New York Agricultural Experiment Station at Cornell gives the following analysis of horse manure:

Water	48.69	per cent
Nitrogen	0.49	“ “
Phosphoric acid	0.26	“ “
Potash	0.48	“ “

The amount of fertilizing compounds in the excrement of animals depends largely on what food the animals received as the following table shows:

Approximate Chemical Content in Pounds in One Ton of Animal Foods

One ton of Animal Food	Nitrogen Pounds	Phosphoric Acid, lbs.	Potash Pounds
Cotton-seed meal	140	60	35
Linseed meal	110	36	27
Gluten meal	110	7	1
Wheat bran	53	58	32
Alfalfa hay	50	11	45
Red clover hay	42	10	40
Oats	40	16	12
Corn fodder with ears	35	11	18
Corn	32	14	8
Corn meal	30	13	8
Timothy hay	25	10	20
Wheat straw	10	3	12
Beets	5	2	10
Corn ensilage	6	3	7
Turnips	4	2	10

It is not unlikely that half of the nitrogen in manure is lost and likely two-thirds of the plant-food value is lost by careless handling before manure produced on farms is returned to the soil. What other business would stand such waste of important material and survive financially?

The smell of ammonia is common in horse stables. The urine is first to undergo bacterial changes by which ammonia is formed and passes into the air rapidly when spread over a wide surface at warm temperatures, particularly when nitrogenous compounds are present.

Manure from pile to wagon, from wagon to piles and then spread. Slow and expensive.

Manure from stable to spreader. The economical way.

Water-tight gutters and floors are important in preventing loss of urine. Concrete in stables is coming into more general use, largely on this account.

Where manure is left exposed to the weather, considerable fertilizing material is lost by leaching. It is sufficiently valuable to justify proper protection. The liquid portion is richer in nitrogen and potash than the solid matter and it is immediately available for plant use. When it cannot be protected, spread it on the land, winter or summer, as soon as possible.

Saving Manure in Stalls.—As the liquid is so valuable, thought should be given to the absorptive qualities of the bedding of animals. The absorptive power of bedding material, in bulk, is as follows:

Oak leaves	162 per cent
Muck	200 " "
Wheat straw	220 " "
Spent tan	450 " "
Peat	600 " "
Dry peat moss	1,300 " "

The floors should be tight, to prevent loss.

Fertilizing Value Per Ton of Various Bedding Material

Ton of Material	Pounds of Nitrogen	Pounds of Phosphoric Acid	Pounds of Potash
Wheat Straw	9.6	4.4	16.4
Oat Straw	14.4	3.6	23.0
Rye Straw	11.2	5.1	18.1
Barley Straw	11.4	5.0	23.5
Pea Straw	20.8	7.0	19.8
Buckwheat Straw	13.0	7.1	24.2
Millet Straw	14.0	3.6	34.0
Soy Bean Straw	14.0	5.0	22.0
Marsh Hay	17.2	10.6	54.0
Leaves	15.0	3.2	6.0

The importance of saving the liquid in manure is still further shown by analysis made at the Massachusetts Experiment Station. The drainage from gutter behind milch cows was found to contain, in 1,000 lbs.:—932 lb. water; 9.8 lb. nitrogen; 2.4 lb. phosphoric acid; and 8.8 lb. potash. Drainage from liquid manure, 1,000 lbs., contained:—820 lb. water; 15.0 lb. nitrogen; 1.0 lb. phosphoric acid; 49.0 lb. potash.

Manure exposed for six months lost by leaching from 42 to 62 per cent in horse manure and 30 per cent in cow manure. When small quantities of land plaster were mixed with the manure the losses were considerably less.

The use of gypsum (**land plaster**) **on manure** will absorb liquid and prevent loss from dripping in handling, retaining much of the ammonia. It should be finely ground and sprinkled on the urine and fresh dung. It can be spread on the floor of the stable when cleaned and before the bedding is spread. Using two to three pounds daily will be sufficient for horses; cattle three to four pounds; and on hen droppings, eight ounces to the pound.

Acid phosphate contains considerable gypsum and its action on manure is somewhat similar to gypsum, also called land-plaster. The soluble calcium acid phosphate combines with and holds the ammonia. It is more effective than gypsum in holding ammonia and costs less.

Fifty pounds of high grade material should be used per ton of manure.

Acid phosphate should not be permitted to come in contact with the animal's feet.

Acid phosphate may be mixed in equal proportions with kainit and used as directed for phosphate alone. Manure so treated will be balanced better, or be a more complete and better fertilizer than when acid phosphate is used alone.

The manure heap may be said to be a chemical laboratory where there is constant bacterial activity. Manure piles are literally alive with bacteria. The heating of manure is what enables the gardener to produce summer temperature in the early spring in hotbeds. Another common sight is the market gardener's large manure pile gradually changing into "well rotted" manure and the farmer's reference to "fire fanging."

The heat generated in the manure pile warms the outside surface where the aerobic bacteria become active, breaking down the insoluble nitrogen compounds, forming ammonia, much of which passes into the air. The ammonia that does not escape in this way may be decomposed into free nitrogen and be lost.

It is a mistaken idea that crops raised on a farm and fed to animals, the manure being returned to the soil, will increase the fertility, without the addition of other fertilizers. In time the fertility in such cases will be considerably reduced. Milch cows and young animals consume from 10 to 50 per cent of the plant food contained in the food thus consumed, so that unless food not produced on the farm, is purchased and fed, the fertility of the soil will gradually be lessened. Animals not increasing in weight or not giving milk may return in excrement plant food nearly equal to that consumed.

Farm manure contains the constituents needed by cultivated crops—nitrogen, phosphorous and potassium. It has the advantage of supplying immediately available plant food while other portions become available later on, as needed by crops.

The mechanical effect of farm manures on the soil is desirable, adding organic matter, which, through its decomposition, makes available insoluble plant-food of the soil, improves the texture, aeration, absorption, warmth, etc. It also supplies food material for soil organisms. The fertility of the soil may be maintained indefinitely by the application of manure, where it is to be had economically.

When used fresh, stable manure stimulates the growth of stem and leaves on account of the high proportion of available nitrogen. It is excellent for spinach and other leaf crops. For general crops market gardeners prefer to let manure become well rotted.

When used fresh on heavy soils, losses through leaching are prevented and what is washed by the rain goes directly into the soil. It also adds beneficial organisms.

On light soil, fresh manure should only be used in moderate amounts or the soil may be made so loose and open that decomposition will be delayed, or, if sufficient moisture is present, decomposition may be so hastened as to heat the soil, dry it out and burn the plants. Generally, well rotted manure should be applied to light or sandy soils.

Fresh manure carries weed seed. Well rotted manure, rots weed seed in decomposing, so there is little trouble on that account and it is a more evenly balanced plant-food. When heavy applications of manure are made to light soils, which is desirable, well rotted manure should be used.

Five tons to the acre is regarded as a light application of manure and twenty tons a heavy application. Small amounts annually should be the rule rather than a heavy application once in several years.

Average Analysis of Manure

Composition of 1,000 lbs. of average barnyard manure moderately rotted:

Water	713.0	Lime	7.0
Organic substance	192.0	Magnesia	1.8
Ash	33.0	Phosphoric acid	2.6
Nitrogen	5.0	Sulphuric acid	1.6
Potash	5.3	Silica and sand	16.8
Soda	1.9	Chlorine and fluorine	1.9

Analysis of Various Manures

Cow Manure

Nitrogen	2.9 per cent
Potash	1.0 per cent
Phosphoric acid	1.7 per cent

Sheep Manure

Nitrogen	5.5 per cent
Potash	1.5 per cent
Phosphoric acid	3.1 per cent

Horse Manure

Nitrogen	4.4 per cent
Potash	3.5 per cent
Phosphoric acid	3.5 per cent

Swine Manure

Nitrogen	6.0 per cent
Potash	2.6 per cent
Phosphoric acid	4.1 per cent

Fertilizing Constituents of Various Barnyard Products.—The figures given here can be accepted only in a general way, as the analyses of material from different sources, made at different times will vary. The analysis of animal manure will vary also according to what the animals have been fed. The tables given can be used as a guide in judging the value of various fertilizing materials.

Material	Water	In 1,000 Pounds			
		Ash	Nitrogen	Phosphoric Acid	Potash
Alfalfa	753	22.5	7.2	1.3	5.6
Apple pomace	805	2.7	2.3	.2	1.3
Barley chaff	130.8	.....	10.1	2.7	9.9
Bat guano	400	.....	82	38	13.1
Bean pods	150	54.7	16.8	2.7	35.5
Beech leaves in autumn	560	21.6	13	.....	4.4
Beet leaves	905	14.6	3	1	4.5
Bone meal	130	232	23	176	1
Buckwheat	160	51.7	13	6.1	24.2
Buckwheat hulls	132	22.3	7.3	4.3	8.2
Cabbage leaves	870	16.9	4.3	1.6	2.2
Castor pomace	95	.....	55	17.5	11
Chicken droppings	560	85	16.3	15.4	8.5
Clover, alsike	820	8.6	5.3	.9	2.4
Clover, crimson	815	18.6	4.5	1.2	4
Clover, red	832	18	6.9	2.1	6.1
Corn cobs, ground*	100	31.8	13.1	.9	2.7
Corn fodder	786.1	48.4	4.1	1.5	3.3
Corn husks	861.9	5.6	1.8	.7	2.2
Corn silage	779.5	.....	2.8	1.1	3.7
Corn stalks	808.6	12.5	2.8	1.4	4.1
Cotton seed cake	112	66.4	62.1	30.5	15.8
Couch grass	143	60	14.1	.....	.....
Droppings, chicken	560	85	16.3	15.4	8.5
Droppings, duck	566	72	10	14	6.2
Droppings, geese	771	95	5.5	5.4	9.5
Droppings, pigeon	519	173	17.6	17.8	10

*Ground corn cobs can be used for stable bedding.

(Table continued on next page)

Fertilizing Constituents of Various Barnyard Products (cont.):

Material	Water	In 1,000 Pounds			
		Ash	Nitrogen	Phosphoric Acifl	Potash
Fir needles	135	12.2	8	1	1.3
Hop leaves and stems	660	41	7.5	4	8.8
Horn meal or shavings	85	230	102	55	.....
Linseed cake	122	51.3	47.2	16.2	12.5
Manure, horse, fresh	713	33	5.8	2.8	5.3
Manure, human, fresh	772	30	10	10.9	2.5
Manure, sheep	646	36	8.3	2.3	6.7
Manure, stable, well rotted	790	65	5.8	3	5
Manure, swine	724	26	4.5	1.9	6
Oak leaves	160	46.1	10	2	3.5
Oat chaff	138	104.7	8	1.4	4.5
Oat straw	90.9	47.6	6.2	2	12.4
Oats, ripening	536	28	5.5	2.6	8.8
Pea pods	130	58.8	17.4	1.7	9.5
Peanut shells	100	29.9	10.4	1.4	8.1
Phosphate, S. Carolina dissolved rock	120	880	.....	152	.....
Rye chaff	143	82.7	5.8	5.6	5.2
Rye straw	76.1	32.5	4.6	2.8	7.9
Salt marsh hay	53.6	.....	11.8	2.5	7.2
Sea weed	150	146.7	16.4	4.2	17.7
Soot, from hard coal	50	281	24	4	1
Sorghum, in bloom	801.5	13.7	3.3	.7	3.4
Soja bean cake	125.9	53.5	66.2	22	18
Straw, oat	90.9	47.6	6.2	2	12.4
Straw, rye	76.1	32.5	4.6	2.8	7.9
Straw, wheat	143	46	4.8	2.2	6.3
Sweet potato vines	800.6	24.5	4.2	.7	7.3
Thomas slag	.....	.....	.....	175	.....
Timothy	700	20.5	5.4	2.4	7.1
Tobacco stalks	618	.....	37.1	6.5	50.2
Tobacco stems	180	64.7	16.4	9.2	28.2
Tomato vines	733	117.2	2.4	.6	2.9
Turnip leaves	898	11.9	3	.9	2.8
Urine, cattle, fresh	938	27.4	5.8	.....	4.9
Urine, horse, fresh	901	28	15.5	.....	15
Urine, human, fresh	963	13	6	1.7	2
Vetch	834	13.9	6.6	1.6	4.1
Wheat straw	143	46	4.8	2.2	6.3
Wood ash, unleached	50	90	.....	35	100

Sewage.—1,000 tons of London crude sewage contained in pounds: ammonia 219; phosphoric acid, soluble 28; phosphoric acid, insoluble 29; potash 51.

Application of Manure.—Manure is sometimes applied directly in the row or hill where the crop will be benefited most quickly. Rotted manure is commonly placed in the hills in planting squash, cucumbers and melons, and produces good results.

The customary way, in large operations is to spread evenly, by hand or with a manure spreader, just before plowing in the spring, covering it about four inches deep in turning the furrow. In light soils the manure may be covered to a greater depth.

Urine contains the plant-food which has been digested and it is in soluble form, practically immediately available. The more digestible a plant food is, the larger the proportion of plant-food in the urine. This shows why the urine produced by farm animals should be carefully preserved and all of it, or as nearly so as possible and applied to the soil. One of the ways to accomplish this is by giving consideration to the bedding material used and preventing leaching by not leaving the mixed manure exposed to rain or permitting the liquid to drain away.

Straw is Largely Used for Bedding.—If it is cut in short pieces it will absorb from twice to three times as much liquid as if uncut. Peat moss absorbs seven times or more of its own weight and retains ammonia. It is valuable as bedding and as poultry litter. Peat and muck, when dry, make retentive bedding material. Manure, where sawdust or shavings have been used as bedding is the least valuable.

A large, moist manure heap becomes compacted beneath the surface where the air is excluded. Here anaerobic bacteria change the insoluble nitrogen into ammonia and unless the manure becomes dry or is exposed to the air in handling, but little ammonia will escape into the air.

If rain washes nitrate nitrogen into the heap from the surface, free nitrogen may be produced from ammonia and lost.

The bacteria at work in the manure pile use nitrate for food, where it becomes insoluble in their bodies. When they die and decompose the nitrogen again becomes soluble.

The straw used in bedding and which is on the surface of the pile, decomposes, being largely changed into carbon dioxide and water. The interior of the pile, where the air is excluded, is attacked by anaerobic organisms changing it into a soft mass which is spoken of as "well-rotted" manure. During the rotting process from a third to a half of the bulk of the manure is lost.

In the rotting process the soluble phosphorous and potassium remain and the insoluble forms become soluble. The nitrogen has been used as food by bacteria and converted into insoluble form in their bodies.

The heat supplied by manure for hotbeds is in reality caused by the burning up of the material although no flame exists. (Fire is often caused by storing hay in barns before it is sufficiently dry, by the same process.)

The breaking down process of the nitrogen-free material used in bedding, by bacteria, takes place rapidly. Oxygen is consumed and the temperature is increased with the supply of air. Temperatures of more than 130 degrees F. drive off ammonia.

Where the air is excluded or moisture is supplied the aerobic bacteria will be discouraged and the anaerobic encouraged, thus reducing the temperature.

Some manures like sheep manure are said to be "hot manures." It is because they are dry, decompose easily and raise the temperature. Cattle manure contains a large percentage of water and is said to be "cold."

Care of Manure.—Where manure is not applied to the land as fast as made, it should be kept as compact as possible and the sides and top made smooth to exclude air, adding water when too much heat is generating, in such quantities only as the pile will absorb, adding acid phosphate and kainit as recommended elsewhere. This material checks the operations of bacteria and is objected to by some on that account. Keeping the manure pile in good form and compact will be found a satisfactory method of handling.

Concrete pits are coming into general use, where manure cannot be hauled immediately to the fields. Covered concrete pits are constructed with open ends, so a team may drive in at one end and out the other. Leaching is prevented by the water tight pit and the roof affords protection from the weather. The manure is spread evenly and properly moistened so fermentation may develop with a minimum loss of nitrogen.

Treatment of Poultry Manure.—Poultrymen and farmers too lightly regard the value of poultry manure. It is valuable and worth giving proper care. In warm weather it easily loses nitrogen. Peat moss over the dropping boards and as litter is desirable for this purpose, or sawdust at the rate of four pounds mixed with ten pounds of droppings. Peat moss is much more desirable than sawdust for this purpose. A complete fertilizer can be made by using two pounds of kainit and four pounds of acid phosphate to ten pounds of droppings.

Poultry Manures, when properly preserved, are the richest of all farm manures. Like other manures, the analysis of poultry manure varies considerably. The following table gives a fair average:

Composition of Poultry Manure

Fowls average 30 to 45 pounds of manure per year.

Kind	Per cent Water	Per cent Nitrogen	Per cent Phosphoric Acid	Per cent Potash
Fresh Hen Manure......	53. 00	1. 40	1. 50	0. 80
Dry Hen Manure.......	8. 35	2. 13	2. 02	0. 994
Fresh Duck Manure....	56. 60	1. 00	1. 40	0. 62
Fresh Goose Manure....	77. 10	0. 55	0. 54	0. 95
Pigeon Manure.........	52. 00	1. 75	1. 75	1. 0

Another Average Analysis of Dry Poultry Manure

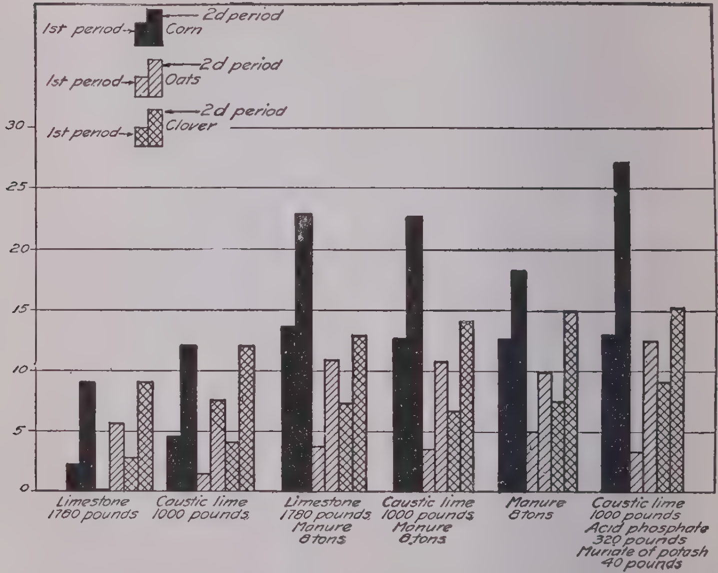
Water............................	0.56 per cent
Nitrogen..........................	1.60 per cent
Phosphoric acid..................	1.75 per cent
Potash...........................	0.90 per cent
Lime.............................	2.25 per cent

Poultry manure should be applied carefully as it has a caustic effect. A safe way is to mix it thoroughly with an equal amount of sand, soil or peat moss.

The money value of various manures is not given, because of the variation in price in different localities, and variation in the price from year to year. Where it is to be had at fair prices, manure is valuable to use in connection with commercial fertilizers, as for example, manure applied liberally for a corn crop. The following year potatoes are grown on the land occupied by the corn the previous year, or wheat might follow corn and then potatoes. Wheat might be injured by fresh manure and potatoes likewise, these crops to be fertilized by commercial fertilizer.

Quantity of Manure.—To estimate the quantity of manure animals will make, multiply the dry matter in the food consumed by the following factors: horse by 2.1; cow by 3.8; sheep by 1.8 and add the weight of the bedding used.

The average horse makes about 50 lbs. of manure daily; cow 95 lbs.; sheep 5 lbs.



RESULTS OF THIRTEEN YEARS' ROTATION

Corn, oats and clover. The 1st period shows results for first seven years; the 2nd period results for last six years. Bushels for grain; pounds for clover. The last corn crop is seen to be almost three times the first corn crop.—Ohio Exp. Agr. Sta.

Chapter XXXIX

CROP ROTATION

Root excretions are detrimental to succeeding crops of the same kind. This is why crops should be rotated, that is, the same kind of a crop on the same land should not be planted a second time, until some other crop has been grown on it. Preferably, the same crop should not be planted again until after two different crops have been grown. The rotation required depends on the kind of crops grown and the character of the soil.

ALFALFA IS GENERALLY FOLLOWED BY CORN

Rotation is planned for crops of different character following each other. For example, a crop of potatoes or turnips or other root crops will be followed by corn or tomatoes or other crops produced above the surface. Some crops are deep rooted like clovers and others more shallow like oats, so the plant food is taken from different strata. Some crops use more nitrogen than others, leaving considerable potassium unused. The following crop will use more potassium and thus the fertilizers which have been applied are more economically used.

Wheat, for example, is used after clover, and oats after wheat, because better crops are produced in this rotation. Wheat is not as able as oats to find and use plant food.

In a four year rotation, with one good application of manure, a leguminous crop will supply what nitrogen is needed.

Hoed or cultivated crops keep the soil open while grass crops tend to compact the soil. The residues left in the soil that injure the crop when produced continuously on the same land are overcome by rotating crops. Diseases, insects and weeds are more troublesome unless rotation is practiced.

A rotation in general use in dairy farming is corn, followed by corn the second year in some cases, followed by oats, seeded with clover and timothy which follow the oats, producing hay. The next season the land is used for pasture and the operation repeated.

In corn growing, corn is produced two years in succession, then wheat or oats and then clover and timothy.

In potato growing, potatoes, wheat or oats, then clover and timothy is the rotation.

Alfalfa is generally grown for four years, followed by corn for two years, then wheat, followed by oats.

Rotation is not followed in cotton growing to the extent it should be. Following a crop of cotton, corn could well be used, with cowpeas broadcast at the last cultivation of the corn. The next year oats followed the same season by cowpeas, then repeating the rotation.

A mixed fertilizer that may give good results one season may not do so the next, with exactly the same formula. Soils are constantly undergoing changes according to the crops produced on them, etc. The organic matter in the soil must be kept up, also the supply of calcium. In central Europe it is common for farmers to supply plant food separately, often applying the nitrogen, phosphoric acid and potassium at different seasons and in varying amounts, according to experience and results which are carefully studied. There is a lesson here for American farmers.

Fertilizer Recommendations.—In a general way manufacturers' recommendations for various crops are as follows:

	Nitrogen	Phosphoric Acid	Potash
For Cereals	3 per cent	8 per cent	10 per cent
" Root Crops	3 " "	8 " "	7 " "
" Grass	3 " "	6 " "	9 " "
" Legumes	1 " "	8 " "	10 " "
" Orchards (apples)	2 " "	5 " "	6 " "
" Orchards (peaches)	4 " "	8 " "	6 " "
" Gardens	5 " "	8 " "	10 " "

In the North, nitrogen alone has produced most satisfactory results on apples.

Leguminous crops are valuable green crop manures, useful also for forage and as hay. Some, such as white clover, are used in lawns.

In the North, red, mammoth alsike, and white and sweet clovers are largely used and in some places alfalfa. This latter does well in Northern New Jersey and in parts of Western New York. Field peas and vetch are also used. In mild to warm climates, crimson clover and cowpeas are used. In the West alfalfa, clovers, soy beans and cowpeas are used.

Legumes require an ample supply of organic matter in the soil. Good drainage is necessary and as acidity is injurious, liming must receive consideration. Legumes also conserve calcium as food and require an abundance of phosphorous and potassium, and generally a little nitrogen to give the plants a good start. From three hundred to five hundred pounds to the acre of a 3-8-8 mixed fertilizer is desirable, harrowed in.

The organic matter may be supplied by farm manure or by turning under some green crop such as rye. Land that has been heavily manured for previous crops will be in good condition in this respect. The soil should be carefully prepared, especially for small seed which should be only lightly covered.

Crimson clover and velvet beans prefer a light sandy soil.

Table of Rotating Fertilizer Crops.—In the following table, all are deep rooted crops except alsike, crimson and white clover, field peas and vetch. Alfalfa is very deep rooted and particularly valuable on this account.

		SEED REQUIRED PER ACRE			
	Duration in years	Green manure	Forage	Planting Season	Depth to plant inches
Alfalfa	4–10	25–35 lb.	20–25 lb.	Early spring or late summer	1½
Soy Bean	1	1–1½ bu.	2–3 pks.	May-June	1–2
Vetch	1	1–1½ bu.	1–1½ bu.	May-August	1–2
Velvet Beans	1	1–4 pks.	1–4 pks.	Spring	1–2
Field Peas	1	2–3 bu.	2–3 bu.	Spring	2–4
Cowpea	1	1½–2 bu.	1–1½ bu.	May-June	1–2
Clover, sweet	2	2–4 pks.	10–12 lb.	March-Sept.	½–1
“ red	2–3	12–15 lb.	8–12 lb.	Early spring or late summer	½–1
“ mammoth red	3–4	15–20 lb.	12–15 lb.	Early spring or late summer	1–2
“ alsike	3–5	12–15 lb.	8–15 lb.	Early spring	½–1
“ crimson	1	15–20 lb.	12–15 lb.	June-October	1–2
“ white	4–5	12–15 lb.	10–12 lb.	Early spring	½–1

Chapter XL

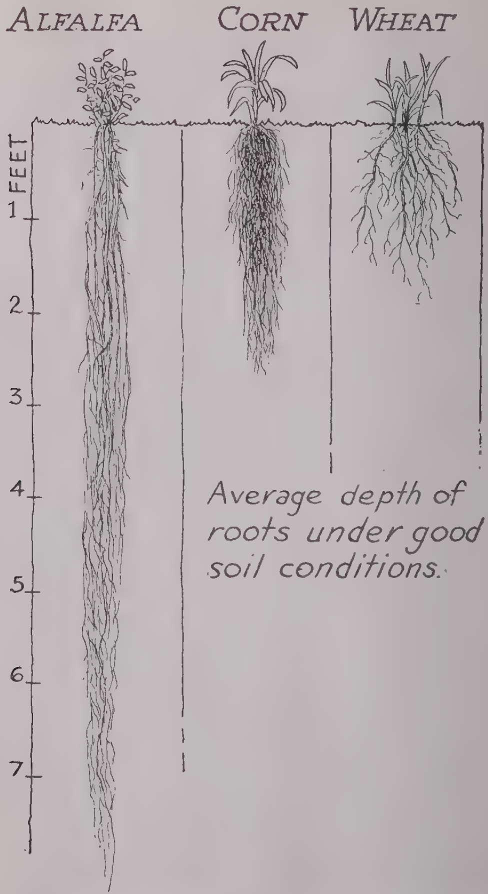
LEGUME CROPS—PASTURES—LAWNS

Alfalfa is by no means a new plant, nor are its uses for fertilizing new. It was used for this purpose by the ancient Greeks and later in Great Britain. The seed was sold nearly a century ago by the early American seedsmen as Lucerne. In the seed business, years ago, when inquiry was made for the seed, knowing its very deep rooting character, purchasers were cautioned that the seedsman would not be responsible for getting it out of their land, once it was planted. This caution was issued to prevent responsibility in case of a law suit for introducing a troublesome weed. Less was known about the crop then than at present.

Alfalfa does not reach a great growth until the second or third year and in good soil, supplied with a proper amount of organic matter and other plant food, if kept free from weeds, will thrive for eight or ten years. On wet soil or heavy clays it may die out in a year or two. The roots go down deeply in the earth for water in open soils and because of this it is not suitable for growing for more than a short time in orchards.

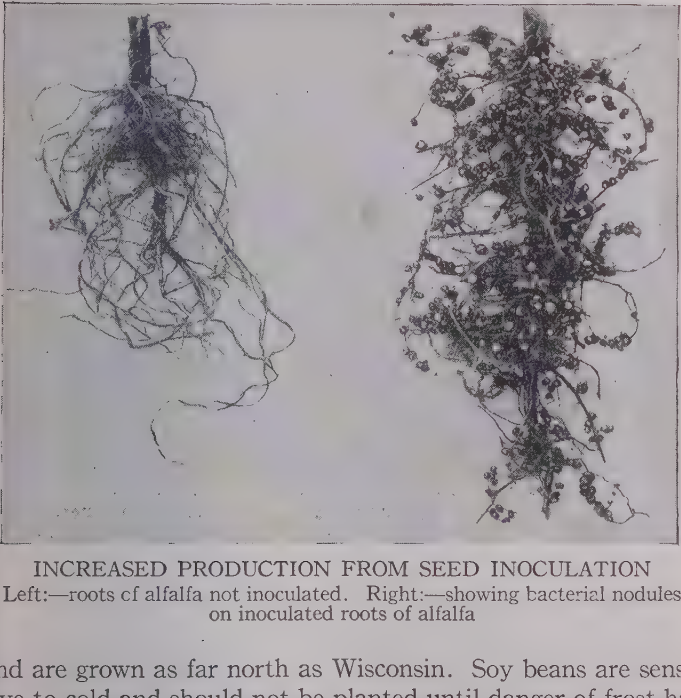
The seed should be inoculated before planting and, after the first year, farm manure or fertilizer should be applied annually. If manure is used, also use one hundred pounds of acid phosphate and fifty pounds of potassium chloride to the acre.

Soy-beans bid fair to become a most important crop in this country. The oil is valuable and the compressed material


ALFALFA
CORN
WHEAT
FEET
1
2
3
4
5
6
7
Average depth of roots under good soil conditions.

DEEP ROOTED ALFALFA BENEFITS THE SOIL
Although it was at one time regarded with great suspicion

remaining makes good food for animals and is valuable also as a fertilizer. They grow on any kind of land that is not too wet and are grown as far north as Wisconsin. Soy beans are sensitive to cold and should not be planted until danger of frost has passed and the soil becomes warm. One and one half to two bushels of seed per acre sown broadcast and covered about two inches deep is proper, or, they may be put in with a drill, the rows twenty inches apart. Soil inoculation is desirable. Two hundred pounds per acre of a 3-8-8 fertilizer cultivated into the soil before seeding is advisable.



INCREASED PRODUCTION FROM SEED INOCULATION
Left:—roots of alfalfa not inoculated. Right:—showing bacterial nodules on inoculated roots of alfalfa

Vetch is more suitable on poor, light soils than either soy beans or cow peas, but winter kills it in the North.

HAIRY VETCH
Sown at last working of tomatoes. Photo taken in November, Camden Co., N. J.—N. J. Exp. Sta.

Hairy vetch stands cold well and makes it desirable for use in the North. It is planted along the last of April to the middle of May and from the middle of August to the middle of September, usually sown broadcast in corn and cotton fields and worked in at the last cultivation. Three hundred pounds of a 3-8-8 fertilizer per acre can be used and as with other legumes, inoculation is desirable.

Velvet Beans are suited to portions of the South, where the weather is warm and moist. The vines are long and often difficult to plow under. The same culture is required as for soy beans.

Field Peas do not thrive on light, dry soils, preferring clay loam and do well on clay. They delight in cool, moist weather, like all peas. Early spring is the time for planting. Started in August or September they will make a good growth before heavy frosts and are turned under in the spring. Peas do better in drills than sown broadcast. Use about two hundred pounds per acre of a 3-8-8 fertilizer at time of seeding.

Cowpeas are best suited to warm sections but some varieties thrive in the North, growing on any soil, not too wet. Sow broadcast or with a drill when the soil is warm. It is a difficult crop to plow under and on light soils, if turned under, may make the soil too open until the material has had time to decay. A good crop will supply nearly two tons of organic matter per acre, containing one hundred pounds of nitrogen, twenty-five pounds of phosphoric acid and one hundred pounds of potash.

SWEET CLOVER
Seeded in corn at the last cultivation.—N. J. State Exp. Sta.

Sweet Clover is found along the roadsides and fence corners in hard, dry soil and was long regarded as a troublesome weed, with a long, tough root. It is one of the best legumes to use on poor soils and its extreme hardiness makes it valuable in the North. It does well without fertilizer. Plow under the second season before the flowering period.

Red Clover thrives on a wide range of soils, providing they are well drained, containing ample organic matter and calcium.

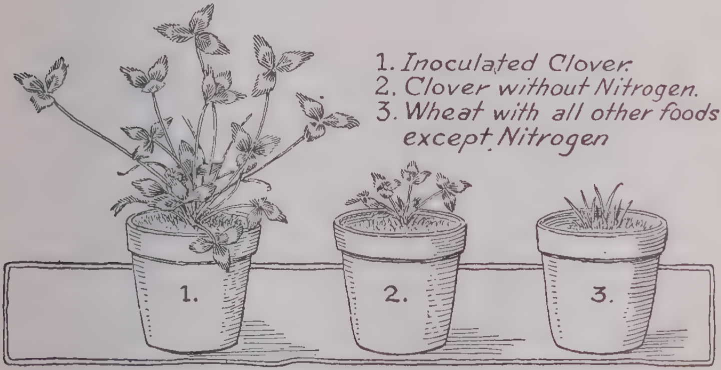
Red clover usually is grown for two years, cut for hay and then turned under, followed by potatoes or corn. The roots constitute a large proportion of the food value of the plants and decompose rapidly. When the whole crop is turned under it will supply approximately per acre, one hundred pounds of nitrogen, fifty pounds of phosphoric acid and one hundred pounds of potash. It is often sown with winter wheat or rye and takes up the fertilizer remaining which was applied for those crops. When sown alone, fertilize as for alfalfa.

When red clover is used as a permanent pasture, liberal amount of phosphorus and potassium should be supplied. Nitrogen if given in more than very modest amounts will cause grasses to thrive and choke out the clover.

Mammoth Red Clover will thrive on wetter lands than red clover. It is coarser and takes longer than red to mature. The cultural treatment is the same as for red clover.

Alsike Clover is adapted to moist clays where other clovers will not thrive. It is of creeping habit and is grown usually with another crop, such as mammoth red. The soil must be well prepared. Three hundred pounds of mixed fertilizer as recommended for alfalfa should be well worked in, close to the surface.

Crimson Clover thrives from Southern New Jersey to Georgia. It is a beautiful and valuable plant and it is unfortunate that a variety has not been produced that will thrive in the North. It grows on light soils where other clovers perish. Crimson clover makes an excellent cover crop for orchards and berry patches and after crops of potatoes and tomatoes. On poor soils use three hundred pounds of a 3-8-8 fertilizer.


1. Inoculated Clover.
2. Clover without Nitrogen.
3. Wheat with all other foods except Nitrogen
1.
2.
3.

A COMPARATIVE DIAGRAM THAT IS SELF-EXPLANATORY

White Clover is used largely in mixtures of lawn grass seed and in mixtures of grasses and clovers for pastures. It is hardier than red clover, growing on poor soil where red clover will perish. The better the soil, however, the better the result. The culture is the same as that for red clover.

Meadows.—Where grass is to be grown continuously from season to season, plants are grown which are ready for cutting at the same time. There are locations on many farms only suitable for use as meadows or pastures. Frequently not much consideration is given them, and as a result they do not yield the return the owner should have.

Clays and loams support good meadows as they hold moisture well and are not difficult to keep in good condition. The plants are more difficult to start on light soil and they run out quicker.

Meadows are started in humid regions by seeding with wheat or rye grasses in the autumn and clovers in the spring.

For a durable permanent meadow the soil must contain an abundance of organic matter and be free from weeds. Where farm manure can be used, from ten to fourteen tons to the acre should be applied to the preceding crop which, like corn, is to be well cultivated to get rid of weeds. If it is necessary to fertilize immediately before sowing the grass crop, use ten tons to the acre, of well rotted manure well worked in. This should be sufficiently rotted so that it contains no weed seed.

Prepare the land by deep plowing, cultivating several times to get out the weeds that would later be troublesome, and to get the soil in good condition.

Unless certain that the supply of calcium is ample, apply from half a ton to a ton to the acre of burnt lime, or, two to three tons of ground limestone to the acre, before the first cultivation. If manure has been added before plowing use ground limestone instead of burnt lime. This application of lime must be repeated every four or five years as a top dressing.

Just before seeding apply five hundred pounds per acre of a 4–8–4 fertilizer in addition to the manure.

Where manure has not been used on the preceding crop or applied directly, five hundred to eight hundred pounds of the following mixture is recommended, but manure is best, if it is to be had:

Mixture A

Sodium nitrate	100 lbs.
Acid phosphate	400 lbs.
Potassium chloride	360 lbs.
Tankage (6.5 per cent nitrogen and 9 per cent phosphoric acid)	700 lbs.
Drier	440 lbs.

(The drier may be sand or dry, pulverized earth.)

Nitrogen applied lightly in the spring gives good results on meadows, but if the crop is clover or partly of clover, the application of nitrogen must be light or the clover will disappear if nitrogen is used alone. Where clovers are in the mixture or grown alone, do not use more than seventy-five to one hundred pounds of sodium nitrate ground fine and mixed with four times its weight of dry inert material—sand, dry earth powdered, etc., to keep it from injuring the plants.

It is advisable also to use in the mixture some acid phosphate and potash which are required by both grasses and clovers. On timothy or mixed grasses double the quantity may be used.

Meadows should have an application of manure or fertilizer in the early spring. If possible use both, alternating each year. The manure should be finely pulverized for best results.

The commercial fertilizer may be applied in the autumn or early spring, using phosphoric acid, potash, and lime if necessary. Nitrogen is a deciding factor in securing a high yield in quantity and quality. Quality means a high protein content and this necessitates the use of a quantity of nitrogen in the early spring. A second application of nitrogen should be made after the first cut, using 100 to 200 pounds of calcium nitrate or nitrate of soda per acre to obtain best results, which will accrue, providing the weather is not unfavorable and that the first cut is not made too late in the season.

A complete fertilizer may be used in the spring, one containing nitrogen, phosphoric acid and potash. For illustration a 4-8-4, using 400 to 600 pounds to the acre. Or, the new highly concentrated fertilizer, nitrophoska may be used at the rate of 100 to 150 pounds to the acre. In addition to this give a summer application of nitrogen.

To assist clovers in meadows a 2–8–10 may be used at about three hundred pounds per acre.

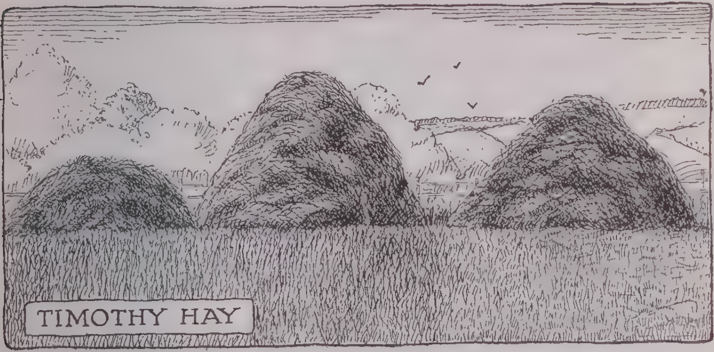
In the East, Italian rye-grass, meadow fescue and red top in mixture, are used on moist soils to establish meadows. On loams and clays, timothy is largely used. Meadow fescue and blue grass are sometimes added. In other combinations, red clover, red top and timothy are added and sometimes, blue grass. Largest yields are obtained where only one kind or not more than two are used.

Timothy is chiefly used for hay because it produces a good crop the first year and runs out in permanent pastures. Use from 12 to 15 lbs. per acre.

Red Top produces the year following sowing. It grows on slightly acid and wet soils, where timothy fails. Use 6 lb. per acre.

Tall Meadow Fescue is used for permanent pasture, as it requires three years to become established, on good soil. Use 8 to 10 lbs. per acre.

Orchard Grass also requires good soil. It stands drought but forms in tufts or clusters. Sow 16 to 20 lbs. per acre.



GRAPHIC ILLUSTRATION OF USE OF FERTILIZER
Pile on left: No fertilizer; 2200 lbs. hay per acre. Center Pile: 600 lbs. Nitrate of Soda, 300 lbs. acid phosphate, 80 lbs. muriate of potash; 7600 lbs. hay per acre. Pile on right: 300 lbs. nitrate of soda, 300 lbs. acid phosphate, 80 lbs, muriate of potash; 7000 lbs. of hay per acre

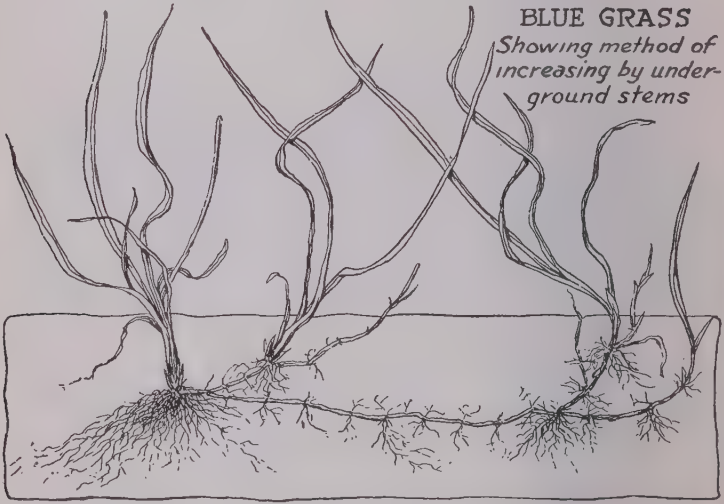
Perennial Rye Grass is the best for wet, marshy land.

Kentucky Blue Grass is used largely in lawns and requires several seasons to mature and is sometimes used in pastures.

Rhode Island Bent is another excellent lawn grass, especially where the soil may be slightly acid. Acid phosphate, and a little potash are its chief fertilizer needs, without lime.

Red Fescue is also largely used in lawns. It thrives on light soils, inclined to dryness and is particularly useful in shady places.

Pastures should have frequent applications of organic matter, fertilizing and seeding, with weeds cut down by mowing before they seed.


BLUE GRASS
Showing method of increasing by underground stems

Chapter XLI

THE CEREALS

The cereals, which are in reality grasses, include corn, wheat, rye, barley, oats, buckwheat, millet and sorghum. Corn is only a largely developed grass. Some of these are used for cutting green and feeding to stock as forage, and the method is called soiling. They are also used for grain, for pastures, for hay, and for cover or green manure crops.

Corn is used as grain, as forage and the stalks and leaves are fed dry. It is more largely used than any other crop for filling silos for winter use, and when cut and stored in silos is called silage. Corn will produce more food per acre than any other grain.

Corn is grown in rotation in the corn states, two years to corn, one to wheat or oats, followed by timothy and clover for three years. This is a six-year rotation.

A four-year rotation used in some sections is corn one year, oats one year, wheat seeded with timothy and clover which is grown two or three years.

In the South a common three-year rotation is corn the first year, followed by oats in the autumn, followed by cowpeas and cotton.

Corn thrives on a great variety of soils from the South to the North and from Maine to Kansas. A rich, warm loam, well drained, with plenty of organic matter and lime, will give the best results. Where there is a prospect of corn growing, it is worth trying, as it is likely to do fairly well, as it does over a wide range of soil and climate.

Corn quite commonly follows grass or clover, in which case plowing should be done in the autumn. Spring plowing should be early. Cultivation should be deep and thorough.

Corn does not germinate and thrive until the ground is warm, nevertheless it has a long growing season and produces heavy grain, stalk and foliage and needs ample plant food.

Farm manure at the rate of eight to ten tons an acre applied in the autumn should be used for corn. If a leguminous crop has been turned under the manure may be cut down to about three tons and four or five hundred pounds per acre used of about a 4-8-6 mixed fertilizer. On light soils it is desirable to obtain the nitrogen only partly from nitrate and the balance in tankage so it will not be so quickly available.

There is nothing equal to liberal amounts of organic matter in the soil. To farm without it is a hard task, if not impossible to do so successfully. Growing corn will emphasize this fact.

Fertilizers should be evenly distributed for corn as the plant roots spread in all directions from the surface down to considerable depth.

The usual distance of planting is three feet apart each way, with three or four seeds in each hill, two or three inches deep.

Cultivate to keep down the weeds and retain soil moisture. When the plants are up, the cultivation must be shallow to avoid disturbing the fine feeding roots, which are close to the surface, but frequent enough to keep down the weeds.

As forage, corn is planted more closely, about twelve to fifteen quarts per acre, planting in rows three feet apart and the plants about six inches apart in the rows. Sometimes corn is sown broadcast for quick growth for green forage.

Wheat.—The rotations for wheat vary in different sections. Some of them are:

Three years:—
  Potatoes, wheat, clover.
  Corn, wheat, clover.

Four years:—
  Corn, oats, wheat, clover.

Five years:—
  Corn two years, oats, wheat, clover; and there are other variations.

Wheat grows on a wide range of soils, but ample organic matter is necessary in any soil for good results. Thorough preparation is also required. Plow as soon as the crop has been removed which it is to follow and harrow frequently to compact and keep down weeds. On light soils often only harrowing is necessary before seeding.

Green crops take the place of manure where manure is lacking, and a good plan is to apply it to the previous crop, using a 3-8-5 commercial fertilizer on the wheat at the rate of 250 to 350 pounds to the acre, which can be applied with the drill by the use of a fertilizer attachment.

When wheat has not wintered well or does not start well in the spring an application of 100 pounds to the acre of nitrate of soda well mixed with an equal quantity of dry earth, broadcast, will start it in active growth. Less trouble and perhaps better results may be obtained by using 75 to 100 pounds to the acre of calcium nitrate (nitrate of lime), not mixed with any other material, spread broadcast by hand or machine.

Cover the seed from one to three inches according to the character of the soil, using eight pecks to the acre, sowing winter wheat sufficiently early so it will make a good start before the ground freezes.

Rye is increasingly used as green manure, on account of its adaptability. It is used in a limited way for pasturage and forage. Its rotations are the same as for wheat, also the culture. Rye thrives on a wide range of soils, where other grains, except buckwheat, will not grow. Heavy clay and wet soil are unsuitable for rye. Winter rye, like winter wheat, should be seeded early enough to give the plants a good start before freezing weather, using from four to eight pecks per acre, preferably in drills. The same fertilizer is used as for wheat. On fairly good soil it will do fairly well without fertilizer.

Oats like soils well supplied with organic matter as they are partial to moisture, but they grow on some very poor soils.

Oats are used in various rotations. In the South oats are grown as a winter crop, the seeding done in the autumn. In the North the seeding is done early in the spring, using two to three bushels to the acre, covering from one to two inches deep.

When oats follow corn on good land which has been well fertilized, the oats being stronger feeders are left to shift for their own food. On poor soils a fertilizer low in nitrate content may be used, about a 3-8-5, three to four hundred pounds per acre.

Barley when sown during August in the North, makes a good forage crop. Its culture is similar to oats, seeding two bushels to the acre. In the South barley is sown in the autumn and used as pasture.

Buckwheat is a short season crop maturing in about ten weeks and perfects its crop at high altitudes. In the Adirondack Mountains in New York State, buckwheat is grown on poor soil and is the one grain that will mature in many sections there. Nevertheless, buckwheat responds well to good soil, good culture and fertilizing, but lodges on soils rich in nitrogen, so acid phosphate and potash are the materials to rely on. In soils well supplied with nitrogen, one hundred and fifty pounds of acid phosphate and forty to fifty pounds of potassium chloride will fill the requirements.

Seeding is done any time from May to August, from three to five pecks per acre, covered two to three inches.

Millet is a good hot weather crop and makes a good cover crop and forage, being ready for cutting in about eight weeks.

Millet should have a mellow seed bed. It will not do well on wet land or heavy clay. It requires warmth and it is useless to sow it before the ground and weather are warm. From three to four pecks are used to the acre.

Sorghum is essentially a poor soil crop and is largely used in dry sections for forage and for syrup and sugar. The culture is the same as for corn, but as it starts slowly clean cultivation is necessary to keep down the weeds. The seed is sown in rows, using ten pounds to the acre, or broadcast requiring about double the quantity. Use stable manure at the rate of eight tons to the acre and a 3-8-5 mixed fertilizer at the rate of two hundred pounds to the acre. For syrup or sugar use from twice to three times the quantity of mixed fertilizer.

Chapter XLII

COMMERCIAL FERTILIZERS

Commercial Fertilizers are produced in the United States to the value of $200,000,000 a year or more. They are called commercial fertilizers, agricultural fertilizers, chemical fertilizers, mixed fertilizers, etc., manufactured chiefly from inorganic materials and also from by products of various industries. Their value depends on the compounds of **nitrogen, phosphorous** and **potassium** which they contain and these, together, are called complete fertilizers.

Special fertilizers are made for special crops or special conditions and may consist of one, or two or three of these plant food constituents in special combinations.

Meaning of Fertilizer Combinations.—Fertilizers are frequently referred to, for example, as a "4–8–4" meaning, in the North, four per cent nitrogen, eight per cent. phosphoric acid and four per cent. potash. In the Southern states, this order is reversed, the first figure representing potash, the second phosphoric acid and the third nitrogen.

In buying fertilizers, not only should the analyses be given, but a statement as to their availability.

Sources of Chemical Fertilizers

Percentage composition of material used as sources of nitrogen.

Material	Nitrogen	Equivalent to Ammonia	Potash K_2O	Phos. Acid Total
Nitrate of soda	15 to 16	18 to 19½		
Calcium nitrate	15 to 16	18 to 19½		
Sulphate of ammonia	19½ to 21	24 to 25½		
Leunasalpeter	26	31½		
Urea	46	55 to 56		
Dried blood –high grade	13 to 14	16 to 17		2 to 3
Dried blood—low grade	10 to 11	12 to 13		1½ to 2
Tankage	5 to 9	6 to 11		9 to 16
Dried fish scrap	9 to 10	11 to 12		5½ to 7
Cotton seed meal	6½ to 7½	7½ to 9	1½ to 2	2 to 3
Castor pomace	5 to 6	6 to 7	1 to 1½	1½ to 2
Tobacco stems	2½ to 3	3 to 3½	2 to 10	½ to 1

Tables for calculating raw fertilizer material required per ton in mixtures of different composition:

Fertilizer material in formula	Per Cent of nitrogen in formula	Equivalent to ammonia per cent.	Factors for calculating fertilizer material from nitrogen	Factors for calculating material from ammonia
			Multiply by	Multiply by
Nitrate of soda	15.0	18.2	133	110
Calcium nitrate	15.0	18.2	133	110
Sulphate of ammonia	20.0	24.3	100	86.4
Leunasalpeter	26.0	31.6	77	63.3
Urea	46.0	55.9	43.5	35.7
Dried blood	12.4	15.0	161	133
Cotton seed meal	7.0	8.5	286	235

	Phosphorous per cent.	Phosphoric acid, per cent.	Factors for calculating material from Phosphorous	Factors for calculating material from phosphoric acid
			Multiply by	Multiply by
Acid phosphate	6.1	14.0	328	143
Basic slag	7.0	16.0	285	125

	Potassium per cent.	Potash per cent.	Factors for calculating material from Potassium	Factors for calculating material from Potash
			Multiply by	Multiply by
Sulphate of potash	40	48	50	42
Muriate (chloride) potash	41.5	50	48	40
Kainit	10	12	200	167

Percentage Composition of Materials Used as Sources of Potassium.

MATERIAL	Sulphate of Potash	Muriate of Potash	Sulphate of Magnesia	Chloride of Magnesia	Chloride of Sodium	Sulphate of Lime	Substances insoluble in water	Water	Calculated to pure potash K_2O	
	K_2SO_4	KCl	$MgSO_4$	$MgCl_2$	NaCl	$CaSO_4$			Average	Guaranteed
Crude Salts										
Kainit	21.3	2.0	14.5	12.4	34.6	1.7	0.8	12.7	12.8	12.4
Carnallit	....	15.5	12.1	21.5	22.4	1.9	0.5	26.1	9.8	9.0
Concentrated Salts										
Sulphate of potash 96%	97.2	0.3	0.7	0.4	0.2	0.3	0.2	0.7	52.7	51.8
" " " 90%	90.6	1.6	2.7	1.0	1.2	0.4	0.3	2.2	49.9	48.6
Sulphate of potash—magnesia	50.4		34.0		2.5	0.9	0.6	11.6	27.2	25.9
Muriate of potash 90-95%	....	91.7	0.2	0.2	7.1		0.2	0.6	57.7	56.8
" " " 80-85%	....	83.5	0.4	0.3	14.5		0.2	1.1	52.7	50.5
Manure salt, min. potash 20%	2.0	31.6	10.6	5.3	40.2	2.1	4.0	4.2	21.0	20.0
" " " " 30%	1.2	47.6	9.4	4.8	26.2	2.2	3.5	5.1	30.6	30.0

Percentage Composition of Materials Used as Sources of Phosphoric Acid.

Material	Total	Available	Insoluble	Nitrogen	Equivalent to Ammonia	Potash K_2O
Acid phosphate	16–19	14–17	1– 2			
Carolina phosphate rock	26–27		26–27			
Dissolved bone-black	17–20	16–18	1– 2			
Bone meal	20–25	5– 8	15–17	1 – 4½	1¼– 5½	
Dissolved bone	15–17	13–15	2– 3	2½– 3½		
Thomas slag	22–24		22–24			
Peruvian guano	15–15	7– 8	5– 8	6 –10	7¼–12	1½–4

Highly Concentrated Compounds

	Nitrogen	Equivalent to Ammonia	Phos. Acid	Potash
No. 1 Nitrophoska	15	18	30	15
No. 2 Nitrophoska	15	18	15	22 chlorine free

No. 2 is used for crops which are sensitive against chlorine, such as tobacco, citrus fruits, hops, flowers. Can be mixed with certain organic material, like cotton seed meal, peat moss, ground tobacco stems, tankage, etc.

Amount of fertilizer removed from an acre of soil by some common crops:

Crop	Yield	Nitrogen Pounds	Potash Pounds	Lime Pounds	Phosphoric Acid Pounds
Wheat	30 bushels	48	28	9	21
Oats	45 "	55	46	11	19
Corn	30 "	43	36	..	18
Potatoes	6 tons	47	76	3	21

How to Find Equivalent Amount of Plant Food Constituents in Different Forms:

To change	ammonia	into an equivalent amount of	nitrogen,	multiply by	0.82
“ “	“	“ “ “ “	“ sodium nitrate,	“	“ 5.0
“ “	“	“ “ “ “	“ ammonium sulphate	“	“ 3.9
“ “	nitrogen	“ “ “ “	“ ammonia,	“	“ 1.2
“ “	“	“ “ “ “	“ sodium nitrate,	“	“ 6.0
“ “	“	“ “ “ “	“ ammonium sulphate,	“	“ 4.8
“ “	sodium nitrate	“ “ “ “	“ ammonia,	“	“ 0.2
“ “	“ “	“ “ “ “	“ nitrogen,	“	“ 0.165
“ “	“ “	“ “ “ “	“ ammonium sulphate,	“	“ 1.55
“ “	ammonium sulphate	“ “ “ “	“ ammonia,	“	“ 0.26
“ “	“ “	“ “ “ “	“ nitrogen,	“	“ 0.21
“ “	“ “	“ “ “ “	“ sodium nitrate,	“	“ 0.64
“ “	potassium nitrate	“ “ “ “	“ nitrogen,	“	“ 0.14
“ “	ammonium nitrate	“ “ “ “	“ nitrogen,	“	“ 0.35
“ “	calcium cyanamid	“ “ “ “	“ nitrogen,	“	“ 0.35
“ “	phosphoric acid	“ “ “ “	“ phosphorous	“	“ 0.44
“ “	“ “	“ “ “ “	“ bone phosphate	“	“ 2.2
“ “	phosphorous	“ “ “ “	“ phosphoric acid,	“	“ 2.3
“ “	potash	“ “ “ “	“ potassium,	“	“ 0.83
“ “	“	“ “ “ “	“ potassium chloride,	“	“ 1.6
“ “	“	“ “ “ “	“ potassium sulphate,	“	“ 1.85
“ “	potassium	“ “ “ “	“ potash,	“	“ 1.2
“ “	“	“ “ “ “	“ potassium chloride,	“	“ 1.9
“ “	“	“ “ “ “	“ potassium sulphate,	“	“ 2.2

To charge	potassium chloride	into an equivalent amount of			
“ “	“ muriate	“ “ “ “	“ potassium,	“	“ 0.53
“ “	“ “	“ “ “ “	“ potash;	“	“ 0.63
“ “	“ sulphate	“ “ “ “	“ potassium,	“	“ 0.45
“ “	“ “	“ “ “ “	“ potash,	“	“ 0.54

To mix a 4–8–4 fertilizer, one containing 4 per cent. nitrogen, 8 per cent. phosphoric acid and 4 per cent. potash, the raw materials needed are figured about as follows

4×133 = 532 lbs. nitrate of soda
8×143 = 1,144 lbs. acid phosphate
4× 40 = 160 lbs. muriate of potash

1,836 lbs. mixture

If it is desired to make a 4–8–4 mixture.—First ascertain how many pounds of nitrogen, acid phosphate and potash in a ton of material made after this formula. The percentage is the amount in 100 pounds. As a ton consists of 2,000 pounds, the percentage must be multiplied by 20, thus:

Nitrogen 4 per cent., 4×20 = 80 lbs.
Acid phosphate, 8 per cent., 8×20 = 160 lb.
Potash 4 per cent., 4×20 = 80 lb.

One hundred pounds of nitrate of soda contains 15 lb. of nitrogen. It will, therefore, require as many times 100 as 15 is contained in 80, or, 533 lbs. of nitrate of soda.

One hundred pounds of acid phosphate contains 14 lb. available phosphoric acid. It will, therefore, require, to furnish 160 lb., as many times 100 as 14 is contained in 160 or 1,143 lb. of acid phosphate.

One hundred pounds of potassium chloride contains 50 per cent. of potash. It will, therefore, require, to furnish 80 lb., as many times 100 as 50 is contained in 80 or 160 lbs. potassium chloride.

Adding these totals gives 1,836 lb.

To make an even ton and insure an exact distribution of the formula prescribed, add 164 lb. to make the even ton of filler, such as fine sand, fine dry muck, peat or earth. Some formulas will figure just an even ton.

To Apply a Specific Amount.—Sometimes instructions may be received to apply a specified amount of nitrogen, available phosphoric acid and potash per acre, as for example 45 lb. nitrogen, 85 lb. phosphoric acid and 50 lb. potash. To find the amount of material necessary to use the operation is as follows:

45 lb. nitrogen × 100 ÷ 15, (the percentage of nitrogen in nitrate) = 300 lb. nitrate of soda.

85 lb. phosphoric acid × 100 ÷ 14, (the percentage of phosphoric acid in acid phosphate) = 607 lbs. acid phosphate.

50 lb. potash × 100 ÷ 50, (the percentage of potash in chloride) = 100 lb. potassium chloride.

The total makes an application of 1,007 lb. of the mixture per acre.

Guaranteed Analysis.—Manufacturers are required by law to state what percentage of nitrogen, phosphoric acid and potassium their fertilizer contains. Some States require, and all States should, the source or form of nitrogen and potassium.

Misleading Analysis.—Guaranteed analysis is sometimes given, evidently to make it appear that the fertilizer contains a larger percentage of plant food materials than it does.

The guarantee will be in the form below giving the percentage of each.

Nitrogen
Equal to ammonia
Soluble phosphoric acid
Equal to bone phosphate of lime
Available phosphoric acid
Equal to bone phosphate of lime
Insoluble phosphoric acid
Equal to insoluble bone phosphate
Total phosphoric acid
Equal to total bone phosphate of lime
Potash
Equal to sulphate of potash

Analyzed, it is found that this means that

Are one and the same thing	Nitrogen Equal to ammonia
Are one and the same thing	Soluble phosphoric acid Equal to bone phosphate of lime Available phosphoric acid Equal to bone phosphate of lime Insoluble phosphoric acid Equal to insoluble bone phosphate Total phosphoric acid Equal to total bone phosphate of lime
Are one and the same thing	Potash Equal to sulphate of potash

An honest form of analysis would state the analysis simply as follows:

Nitrogen	4 per cent.
Available phosphoric acid	8 " "
Potash	4 " "

In guarantees, the total amount of nitrogen is stated, regardless of its form. It may be nitrate, ammonia or organic nitrogen, regardless of whether the nitrogen is quickly available or not. Sometimes it is stated that the nitrogen is from organic matter and in such cases neither nitrate, ammonia nor cyanamid is present. The nitrogen may be from hair or ground leather, which is practically useless. Or the nitrogen may be from dried muck which the farmer can better buy at home. Nitrogen from animal matter indicates the use of fish, bone, blood, meat, horn or hoof meal, but it may also mean leather and hair.

Nitrogen, "equal to" or "equivalent to" ammonia does not mean that the fertilizer contains ammonia, but that if the nitrogen were in the form of ammonia, there would then be the percentage stated.

A pound of ammonia does not contain a pound of nitrogen, although dealers sometimes use the word ammonia when speaking of nitrogen. Ammonia consists of nitrogen in combination with hydrogen. One hundred pounds of ammonia contains 82½ lb. of nitrogen and 17⅔ lb. of hydrogen. It is on this account that the stated percentage of nitrogen as ammonia is higher than for nitrogen, which may deceive the purchaser.

Phosphoric acid is stated in some analyses, as shown in the specimen, in several different forms: Phosphorous in phosphate compounds is present in fertilizers; (1) generally is in compounds of acid calcium phosphate which is water soluble; (2) in reverted phosphate which is, chemically, dicalcium phosphate and which is not water soluble, but is soluble in a solution of ammonium citrate; and (3) in insoluble phosphate, chemically, tricalcium. The total phosphoric acid includes all the phosphorous contained in the fertilizer.

Available phosphoric acid includes the total of the first two forms above stated. The last form is insoluble.

Phosphoric acid equal to bone phosphate, although required by law in fertilizer analysis in some States is pure "bunk" and meaningless to the user of fertilizer. Purchasers should pay no attention whatever to it in considering the analysis.

Fertilizer analysis should state the percentage of water soluble potash as, otherwise, potash materials might be used which would be unavailable.

Sulphate of potash, abbreviated as S. or Sul. Potash (potassium oxide), contains almost double the amount of potash contained in potassium oxide. Ten per cent. of potassium oxide represents the same amount of potassium as 18.5 per cent. of sulphate of potash.

In purchasing fertilizers, separate or mixed, do so under a guaranteed analysis, stating in what form the nitrogen is, whether as nitrate, ammonia, cyanamid, blood, meat, fish, hair, leather, etc. That is the only way to know what the results will be.

The phosphoric acid or phosphorous should be stated as water soluble and reverted for superphosphate materials. The potassium content should also be plainly stated.

When two figures are given in the analysis, such as, phosphoric acid 8 to 10 per cent., consider the lower figure only as that is all the law requires.

High Grade and Low Grade Fertilizers.—Fertilizers are frequently spoken of as high grade or low grade. High grade fertilizers contain large amounts of nitrogen, phosphorous and potassium that are quickly available. Low grade fertilizers contain small amounts in less available form. As a general rule, while high grade fertilizers cost more per pound, they supply the most plant food per dollar of cost. It must be borne in mind, however, that some fertilizing materials are especially valuable for some particular crops, when they would be of considerably less value for others.

Determining the Value of Fertilizers.—The value of fertilizing material is constantly changing. The State Experiment Stations of most States, each year issue a list showing the price the separate ingredients would cost if purchased separately in the principal markets of the country.

The percentage of nitrogen, phosphoric acid and phosphate, such as 5–8-5, represents the number of pounds in one hundred pounds of fertilizer. Multiply the percentage of each constituent by the price quoted in the list of the State College, add these, and to obtain the value per ton, multiply the total by 20.

Filler in Fertilizers.—There is likely to be a misconception as to the amount of inert material in commercial fertilizers. Thus in a 4–8–4 fertilizer, for example the impression may be that four per cent. is nitrogen, eight per cent. phosphorous and four per cent. potash, a total of sixteen per cent., and that the remaining eighty-four per cent. is useless filler.

The elements above named are in a pure or free state as fertilizers. Nitrogen, it has been explained, is a gas, abundant in the atmosphere but it cannot be utilized by any crops, except the legumes. Potassium and phosphorous would be unfit to apply to the soil in a free state and are costly to prepare.

Sodium nitrate in the pure state contains 16.5 per cent. of nitrogen and the sodium and oxygen that make up the remaining 83.5 per cent. are essential to the existence of sodium nitrate.

Potassium chloride or muriate is 52.3 per cent. potassium, and 47.7 per cent. of chlorine present is as necessary to the formation of potassium chloride as is the potassium itself.

Finally, if a superphosphate was prepared from pure calcium phosphate and sulphuric acid, it would contain only 12.2 per cent. of phosphorous. It would also contain 23.7 per cent. of calcium and the sulphur, hydrogen and oxygen constituting the remainder of the superphosphate without which it could not exist, make up 64.1 per cent. of the substance.

A fertilizer compounded of 1,200 pounds of such pure phosphate, 500 pounds of pure sodium nitrate and 300 pounds of pure potassium chloride per ton, would be pure fertilizer, yet it would contain only 4.1 per cent. of nitrogen, 7.3 per cent. of phosphorous and 7.8 per cent. of potassium, or a total of 19.2 per cent. The remaining elements are unavoidably present, as plants cannot utilize the free elements, but must receive them in compounds.

Materials like sodium nitrate, kainit, potassium chloride, etc., absorb moisture and harden on standing. This is prevented by using with them, dry, inert material that will hold moisture and prevent hardening.

Mixing Fertilizers at Home.—Fertilizing materials can be purchased, such as urea, nitrate of soda or sulphate of ammonia, leunasalpeter, acid phosphate, chloride of potash, dried blood, ground bone, ground fish or other materials, mixing them at home to make a complete fertilizer.

Home mixing, as it is called, has decided advantages where special crops are grown. Some plants respond better to one material used as a fertilizer and some to others. Home mixing gives the grower an opportunity to experiment and he may in this way gain knowledge that would never be acquired if mixed fertilizers were always used. On the other hand, where only a few standard crops are grown, such as corn, wheat, oats, hay and potatoes, mixed fertilizers of proper analysis will give satisfactory results and save the labor of mixing.

To mix fertilizers on the farm a smooth, tight floor in the barn, a tamper to break hard lumps, a shovel and a hoe will be needed, if only moderate quantities are to be mixed, as the material will be purchased in small quantities and will come in uniform packages of known weight which can be assembled in proper proportions. For large operations, in addition to the above, a sand screen, a grinding machine and a mixing machine will be needed, but considerable mixing can be done with the tools first mentioned.

A feed grinding mill answers for grinding coarse material. Special grinding machines are made that may also be used for grinding limestone. Nitrate of soda, urea, leunasalpeter, ammonium and potassium compounds and others which have been ground may become lumpy and require regrinding.

Acid phosphate, fish scrap and tankage when ground become sticky. The mill should be set to break the lumps without grinding the material.

For accuracy, each material should be weighed. If the quantity is sufficient, it is sifted through the screen and the lumps are pulverized with the tamper or grinding machine. Keep the screen and mill clean while in use and clean immediately after using. Small quantities of material can be pulverized, if lumpy, with a shovel or tamper.

Spread the bulkiest material on the smooth barn floor in about a six inch layer. On this spread evenly the next bulkiest material with the least bulky material on top. Beginning at one side, shovel the whole pile over, keeping the shovel sliding on the floor in taking each shovelful. Level the pile and shovel it over again in the same way three or four times until the mass is thoroughly mixed.

When a mixing machine is used, the materials in proper amounts are put in and the machine operated.

Sodium nitrate, calcium nitrate, kainit, potassium chloride, etc., absorb moisture and are likely to harden on standing. This can be prevented by using, with them, finely ground or screened dry muck, peat, peat moss, sand, coal ashes, sawdust or gypsum.

Materials for home mixing should be purchased and the mixing done in the winter when work is slack. The State Agricultural Experiment Stations will supply the addresses of dealers who handle the materials.

Mixtures That Should Not Be Used in Combination.—Alkaline compounds set free ammonia from ammonium compounds and therefore should not be mixed or used in combination.

Do not Mix any of these	With
Calcium hydroxide, slaked lime Calcium oxide, quicklime Wood ashes Basic slag phosphate Basic calcium nitrate	Ammonium sulphate Animal manure Bone Blood Tankage Horn Nitrogenous guanos
Calcium hydroxide Calcium oxide Calcium carbonate Wood ashes Basic calcium nitrate	Soluble phosphates Superphosphate Acid phosphate, etc.

Nitrate of soda, kainit and potash materials absorb moisture and when mixed with lime, unless used at once, will harden and be troublesome to handle.

Calculating Amount of Material

Sodium nitrate (nitrate of soda) usually contains 15 per cent of nitrogen.

Acid phosphate, 14 per cent of available phosphoric acid.

Potassium chloride, 50 per cent of potash.

Distributing Fertilizer.—Fertilizer distributed by machinery gives better results than hand-sown, on large fields. Small gardens are easily handled by hand. Seed drills are provided with an attachment for handling the fertilizer when the seed is sown. Broadcasting machines distribute the fertilizer uniformly over the surface. In this case it is harrowed in before sowing the seed to keep it from coming into direct contact with the seed.

Where fertilizer is used when the seed is sown, it should be deposited below the seed, so it will have a covering of soil on which the seed rests.

Where large quantities of fertilizers are used on garden crops, broadcast and harrow before planting. If fertilizer is to be used with the seed, only a small quantity will then be needed.

Chapter XLIII

FERTILIZERS FOR DIFFERENT CROPS

Fertilizers for Different Crops.—Fertilizer recommendations can only be made in a general way. Different crops, on different soils, in different climates will require experimenting to determine what is best. Not even a soil analysis will show conclusively what fertilizer may be best to use.

The following suggestions as to fertilizers for various crops will form a general basis on which to work, varying as experience and experiments may suggest. They differ somewhat from recommendations made elsewhere in this work.

For leguminous crops a formula is recommended of 1-8-10 in the order of nitrogen, phosphoric acid and potash.

For Cereals	3–8–5
“ Garden Crops	4–8–10
“ Grass and Forage Crops	4–6–9
“ Orchards	3–5–10
“ Root Crops	3–8–7

Using from 150 to 300 pounds to the acre.

For silage, where excessive top growth is desired, 500 pounds to the acre.

For garden and root crops use from 700 to 1,500 pounds to the acre.

The formulas given in the tables that follow in this chapter are based on materials of the following composition:

Nitrate of soda, 95 per cent pure, containing 16 per cent of nitrogen.

Dried blood, containing 10 per cent of nitrogen.

Sulphate of ammonia, containing 20 per cent of nitrogen.

Bone meal, containing 20 per cent total of phosphoric acid, one-half calculated as available the first season, also containing 4 per cent of nitrogen.

Dissolved bone, containing 15 per cent of available phosphoric acid and 3 per cent of nitrogen.

Dissolved bone-black, containing 15 per cent of available phosphoric acid.

Dissolved rock (acid phosphate), containing 12 per cent of available phosphoric acid.

Muriate of potash, 80 per cent pure, containing 50 per cent of potash. Sulphate of potash, 90 to 95 per cent pure, containing 50 per cent of potash.

Kainit, containing 12 to 13 per cent of potash.

Wood ashes, containing 5 per cent of potash.

KEY TO TABLES

Nitrogen
A = Nitrate of Soda
B = Sulphate of Ammonia
C = Dried Blood
D = Stable Manure

Available Phosphoric Acid
E = Bone Meal
F = Dissolved Bone
Bone Black
G = Acid Phosphate (Dissolved Rock)

Potash
H = Muriate of Potash
Sulphate of Potash
I = Kainit
J Wood Ashes

In the formulas that follow, that are given in figures, such as 1-8-10, the first figure represents the percentage of **nitrogen** in the formula, the second figure represents the percentage of available **phosphoric acid** and the third figure represents the percentage of **potash.**

TABLES

Alfalfa, 1-8-10, composed of:

30 to 60 lb. A: or
25 to 50 lb. B: or
50 to 100 lb. C: or
1,000 to 2,000 lb. D:
used with
300 to 600 lb. E: or
200 to 400 lb. F: or
250 to 500 lb. G:
used with

80 to 160 lb. H: or
325 to 650 lb. I: or
800 to 1,600 lb. J
to the acre.

(For alfalfa calcium nitrate is recommended, 30 to 60 lbs. to the acre.)

Detailed Example Showing Application of Above Table

30 to 60 lb. nitrate of soda
300 to 600 lb. acid phosphate
80 to 160 lb. muriate of potash

all thoroughly mixed and evenly spread over an acre of land.

Another mixture that will give the same result might be:

25 to 50 lb. sulphate of ammonia
200 to 400 lb. dissolved bone or bone black
325 to 650 lb. kainit.

Or if other materials were more convenient for use, the mixture might be composed as follows:

1,000 to 2,000 lb. stable manure
250 to 500 lb. acid phosphate
800 to 1,600 lb. wood ashes.

In every instance the combination should consist of nitrogen, phosphoric acid phosphate and potash of the weight stated, per acre or per tree, as stated in each formula.

Apples,

Only nitrogen has given results on apples up to the present time, 3 to 8 lbs. nitrate of soda or calcium nitrate to a bearing tree.

Asparagus, 5-7-9, composed of:

120 to 240 lb. A: or
200 to 400 lb. C: or
4,000 to 8,000 lb. D:
used with
300 to 600 lb. E: or
200 to 400 lb. F: or
250 to 500 lb. G:
used with
70 to 140 lb. H: or
300 to 600 lb. I: or
700 to 1,400 lb. J
to the acre.

Later, top dress with nitrate alone or calcium nitrate.

Barley, 4-7-8, composed of:

75 to 150 lb. A: or
50 to 120 lb. B: or
50 to 100 lb. leunasalpeter, or
125 to 250 lb. C: or
2,500 to 5,000 lb. D:
used with
200 to 400 lb. E: or
150 to 300 lb. F: or
175 to 350 lb. G:
used with
50 to 100 lb. H: or
200 to 400 lb. I: or
500 to 1,000 lb. J:
to the acre.

Beans, 1-7-9, composed of:
30 to 60 lb. A: or
30 to 60 lb. calcium nitrate, or
10 to 20 lb. urea or
25 to 50 lb. B: or
50 to 100 lb. C: or
1,000 to 2,000 lb. D:
used with
300 to 600 lb. E: or
200 to 400 lb. F: or
250 to 500 lb. G:
used with
70 to 140 lb. H: or
300 to 600 lb. I: or
700 to 1,400 lb. J
to the acre.

Beets, 5-6-9, composed of:
120 to 240 lb. A: or
120 to 240 lb. calcium nitrate, or
100 to 200 lb. B: or
60 to 120 lb. leunasalpeter, or
40 to 80 lb. urea or
200 to 400 lb. C: or
4,000 to 8,000 lb. D:
used with
250 to 500 lb. E: or
175 to 350 lb. F: or
200 to 400 lb. G: used with
70 to 140 lb. H: or
300 to 600 lb. I: or
700 to 1,400 lb. J
to the acre.

Blackberries, 3-6-8, composed of:

100 to 200 lb. A: or
75 to 150 lb. B: or
75 to 120 lb. leunasalpeter, or
35 to 70 lb. urea, or
150 to 300 lb. C: or
3,000 to 6,000 lb. D:
used with
300 to 600 lb. E: or
200 to 400 lb. F: or
250 to 500 lb. G:
used with
80 to 160 lb. H: or
300 to 600 lb. I: or
800 to 1,600 lb. J
to the acre.

Buckwheat, 4-8-9, composed of:

90 to 180 lb. A: or
90 to 180 lb. calcium nitrate, or
75 to 150 lb. B: or
75 to 120 lb. leunasalpeter, or
30 to 60 lb. urea, or
150 to 300 lb. C: or
3,000 to 6,000 lb. D:
used with
300 to 600 lb. E: or
200 to 400 lb. F: or
250 to 500 lb. G:
used with
70 to 140 lb. H: or
300 to 600 lb.

700 to 1,400 lb. J
to the acre.

Cabbage, 4-7-9, composed of:

250 to 500 lb. A: or
250 to 500 lb. calcium nitrate, or
200 to 400 lb. B: or
175 to 300 lb. leunasalpeter, or
90 to 180 lb. urea, or
400 to 800 lb. C: or
8,000 to 16,000 lb. D:
used with
700 to 1,400 lb. E: or
500 to 1,000 lb. F: or
600 to 1,200 lb. G:
used with
180 to 360 lb. H: or
700 to 1,400 lb. I: or
1,800 to 3,000 lb. J
to the acre.

Carrots, 3-7-8, composed of:

90 to 180 lb. A: or
90 to 180 lb. calcium nitrate, or
75 to 150 lb. B: or
60 to 120 lb. leunasalpeter, or
30 to 60 lb. urea, or
150 to 300 lb. C: or
3,000 to 6,000 lb. D:
used with

350 to 700 lb. E: or
250 to 500 lb. F: or
300 to 600 lb. G:
used with
80 to 100 lb. H: or
300 to 600 lb. I: or
800 to 1,600 lb. J
to the acre.

Celery, 5-6-8, composed of:

250 to 500 lb. A: or
250 to 500 lb. calcium nitrate, or
200 to 400 lb. B: or
90 to 180 lb. urea, or
400 to 800 lb. C: or
8,000 to 16,000 lb. D:
used with
500 to 1,000 lb. E: or
350 to 700 lb. F: or
400 to 800 lb. G:
used with
130 to 260 lb. H: or
500 to 1,000 lb. I: or
1,300 to 2,600 lb. J
to the acre.

Cauliflower. Same as for Cabbage.

Cherries. Same as for Apples.

Clover. Same as for Alfalfa.

Corn, 2-7-6, composed of:

60 to 120 lb. A: or
60 to 120 lb. calcium nitrate, or
50 to 100 lb. B: or
40 to 80 lb. leunasalpeter, or
100 to 120 lb. C: or
2,000 to 4,000 lb. D:
used with
350 to 700 lb. E: or
250 to 500 lb. F: or
300 to 600 lb. G:
used with
60 to 120 lb. H: or
250 to 500 lb. I: or
600 to 1,200 lb. J
to the acre.

Cucumbers, 4-6-8, composed of:

180 to 360 lb. A: or
180 to 360 lb. calcium nitrate, or
150 to 300 lb. B: or
300 to 600 lb. C: or
6,000 to 12,000 lb. D:
used with
500 to 1,000 lb. E: or
350 to 700 lb. F: or
400 to 800 lb. G:
used with
130 to 260 lb. H: or
500 to 1,000 lb. I: or
1,300 to 2,600 lb. J
to the acre.

Currants, 2-5-8, composed of:

60 to 120 lb. A: or
60 to 120 lb. calcium nitrate, or
50 to 100 lb. B: or
100 to 200 lb. C: or
2,000 to 4,000 lb. D:
used with
250 to 500 lb. E: or
175 to 350 lb. F: or
200 to 400 lb. G:
used with
80 to 160 lb. H: or
320 to 640 lb. I: or
800 to 1,600 lb. J
to the acre.

Egg-Plant, 4-5-9, composed of:

240 to 480 lb. A: or
240 to 480 lb. calcium nitrate, or
200 to 400 lb. B: or
80 to 160 lb. urea, or
400 to 800 lb. C: or
8,000 to 16,000 lb. D:
used with
500 to 1,000 lb. E: or
350 to 700 lb. F: or
400 to 800 lb. G:
used with
180 to 360 lb. H: or
700 to 1,400 lb. I: or
1,800 to 3,600 lb.J
to the acre.

Gooseberries. Same as Currants.

Grapes. Use 100 to 300 lb. of nitrate of soda or calcium nitrate or 75 to 250 lb. sulphate of ammonia, or 60 to 200 lb. leunasalpeter, or 35 to 100 lb. urea.

Grass for Meadows or Pastures, 4-8-4, composed of:

150 to 300 lb. A: or
100 to 200 lb. B: or
150 to 250 lb. calcium nitrate, or
50 to 85 lb. urea, or
3,000 to 6,000 lb. D:
used with
250 to 500 lb. G:
used with
80 to 160 lb. H: or
800 to 1,600 lb. J
to the acre.

To be used as a spring application. Follow with summer applications of nitrogen.

Grass for Lawns, 5-6-8, composed of:

120 to 240 lb. A: or
100 to 200 lb. B: or
200 to 400 lb. C: or
40 to 80 lb. urea
used with
250 to 500 lb. E: or
175 to 350 lb. F: or
200 to 400 lb. G:
used with
60 to 120 lb. H: or
250 to 500 lb. I: or

600 to 1,200 lb. J
to the acre.

For summer application use urea alone, or some other form of nitrogen.

Hops, 3-6-12, composed of:

120 to 240 lb. A: or
100 to 200 lb. B: or
200 to 400 lb. C: or
4,000 to 8,000 lb. D, or
40 to 80 lb. urea. Used with excellent results in Europe
used with
350 to 700 lb. E: or
250 to 500 lb. F: or
275 to 550 lb. G:
used with
200 to 400 lb. H: or
800 to 1,600 lb. I: or
2,000 to 4,000 lb. J
to the acre.

Horse Radish, 4-6-9, composed of:

90 to 180 lb. A: or
75 to 150 lb. B: or
150 to 300 lb. C: or
3,000 to 6,000 lb. D, or
90 to 180 lb. calcium nitrate
used with
250 to 500 lb. E: or
175 to 350 lb. F: or
200 to 400 lb. G:
used with
70 to 140 lb. H: or

275 to 550 lb. I: or
700 to 1,400 lb. J
to the acre.

Lettuce, 5-6-9, composed of:

250 to 500 lb. A: or
200 to 400 lb. B: or
400 to 800 lb. C: or
8,000 to 16,000 lb. D, or
250 to 50 lb. calcium nitrate
used with
500 to 1,000 lb. E: or
350 to 700 lb. F: or
400 to 800 lb. G:
used with
150 to 300 lb. H: or
600 to 1,200 lb. I: or
1,500 to 3,000 lb. J
to the acre.

Millet. Same as for Grass for Meadows or Pastures.

Muskmelons. Same as for Cucumbers.

Nursery Stock, Young Trees and Shrubs, etc., 3-6-7, composed of:

60 to 120 lb. A: or
50 to 100 lb. B: or
100 to 200 lb. C: or
2,000 to 4,000 lb. D, or
20 to 40 lb. urea
used with
250 to 500 lb. E: or
175 to 350 lb. F: or

200 to 400 lb. G:
used with
60 to 120 lb. H: or
240 to 480 lb. I: or
600 to 1,200 lb. J
to the acre.

Oats, 4-6-9, composed of:
75 to 150 lb. A: or
60 to 120 lb. B: or
120 to 240 lb. C: or
2,500 to 5,000 lb. D, or
75 to 150 lb. calcium nitrate
used with
200 to 400 lb. E: or
140 to 280 lb. F: or
160 to 320 lb. G:
used with
60 to 120 lb. H: or
250 to 500 lb. I: or
600 to 1,000 lb. J
to the acre.

Onions, 5-6-9, composed of:
270 to 540 lb. A: or
225 to 450 lb. B: or
450 to 900 lb. C: or
9,000 to 18,000 lb. D, or
270 to 540 lb. calcium nitrate
used with
550 to 1,100 lb. E: or
385 to 770 lb. F: or
450 to 900 lb. G:
used with

160 to 320 lb. H: or
650 to 1,300 lb. I: or
1,600 to 3,200 lb. J
to the acre.

Parsnips, 3-9-8, composed of:
120 to 240 lb. A: or
100 to 200 lb. B: or
200 to 400 lb. C: or
4,000 to 8,000 lb. D, or
120 to 240 lb. calcium nitrate
used with
550 to 1,100 lb. E: or
375 to 750 lb. F: or
450 to 900 lb. G:
used with
100 to 200 lb. H: or
400 to 800 lb. I: or
1,000 to 2,000 lb. J
to the acre.

Peaches. The same as apples. 2 to 5 lb. per tree.

Pears. Same as for apples.

Peas. Same as for beans.

Plums. Same as for cherries.

Potatoes, 5-8-7, composed of:
250 to 350 lb. A: or
180 to 280 lb. B: or
85 to 120 lb. urea
used with
400 to 600 lb. G:
used with

100 to 200 lb. H:
to the acre.

Pumpkins. Same as for cucumbers.

Quinces. Same as for apples.

Radishes, 3-7-9, composed of:

90 to 180 lb. A: or
75 to 150 lb. B: or
150 to 300 lb. C: or
90 to 180 lb. calcium nitrate, or
30 to 60 lb. urea
3,000 to 6,000 lb. D:
used with
350 to 700 lb. E: or
250 to 500 lb. F: or
280 to 560 lb. G:
used with
90 to 180 lb. H: or
350 to 700 lb. I: or
900 to 1,800 lb. J
to the acre.

Raspberries, 2-7-10, composed of:

75 to 150 lb. A: or
60 to 120 lb. B: or
120 to 240 lb. C: or
75 to 150 lb. calcium nitrate
2,400 to 4,800 lb. D:
used with
400 to 800 lb. E: or
280 to 560 lb. F: or
320 to 640 lb. G:
used with

120 to 240 lb. H: or
480 to 960 lb. I: or
1,200 to 2,400 lb. J
to the acre.

Rye. Same as for oats.

Sorghum. Same as for corn.

Spinach, 2-7-5, composed of:
90 to 180 lb. A: or
75 to 150 lb. B: or
90 to 180 lb. calcium nitrate, or
30 to 90 lb. urea, if used with bone
3,000 to 6,000 lb. D:
used with
550 to 1,100 lb. E: or
375 to 750 lb. F: or
450 to 900 lb. G:
used with
80 to 160 lb. H: or
320 to 640 lb. I: or
80 to 1,600 lb. J
to the acre.

Squashes. Same as for cucumbers.

Strawberries, 3-7-9, composed of:
150 to 300 lb. A: or
125 to 250 lb. B: or
50 to 100 lb. urea, or
250 to 500 lb. C: or
5,000 to 10,000 lb. D:
used with
550 to 1,100 lb. E: or

375 to 750 lb. F: or
450 to 900 lb. G:
used with
140 to 280 lb. H: or
550 to 1,100 lb. I: or
1,400 to 2,800 lb. J
to the acre.

Tobacco, for the South, **4-6-10,** composed of:
180 to 360 lb. A: or
150 to 300 lb. B: or
6,000 to 12,000 lb. D:
used with
500 to 1,000 lb. E: or
350 to 700 lb. F: or
400 to 800 lb. G:
used with
160 to 320 lb. sulphate of potash, or
1,600 to 3,200 lb. J
to the acre.

Tobacco, 5-4-5, for Connecticut, composed of:
250 to 350 lb. A: or
180 to 280 lb. B: or
700 to 900 lb. cotton seed meal or
85 to 120 lb. urea
used with
250 to 300 lb. G: or
200 to 250 lb. F: or
300 to 400 lb. E:
used with
80 to 120 lb. sulphate of potash.

These quantities make approximately a **5-4-5** formula. Double these quantities to be used per acre.

Tomatoes, 4-6-7, composed of:
150 to 300 lb. A: or
125 to 250 lb. B: or
250 to 500 lb. C: or
50 to 100 lb. urea
5,000 to 10,000 lb. D:
used with
350 to 700 lb. E: or
250 to 500 lb. F: or
280 to 560 lb. G:
used with
80 to 160 lb. H: or
320 to 640 lb. I: or
800 to 1,600 lb. J
to the acre.

Turnips. Same as for beets.

Watermelons. Same as for cucumbers.

Wheat 4-7-4, composed of:
75 to 150 lb. A: or
60 to 120 lb. B: or
120 to 240 lb. C: or
75 to 150 lb. calcium nitrate
2,400 to 4,800 lb. D:
used with
200 to 400 lb. E: or
140 to 280 lb. F: or
160 to 320 lb. G:
used with
25 to 50 lb. H: or
100 to 200 lb. I: or
250 to 500 lb. J
to the acre.

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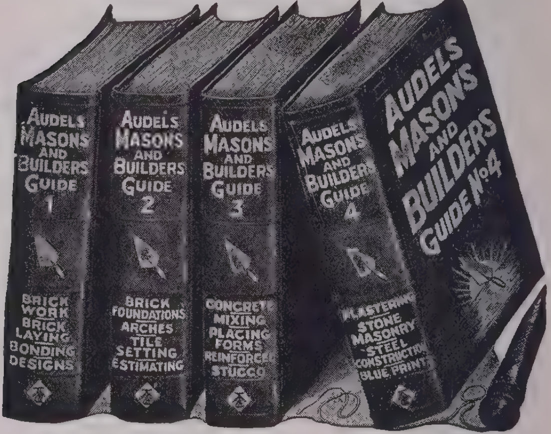
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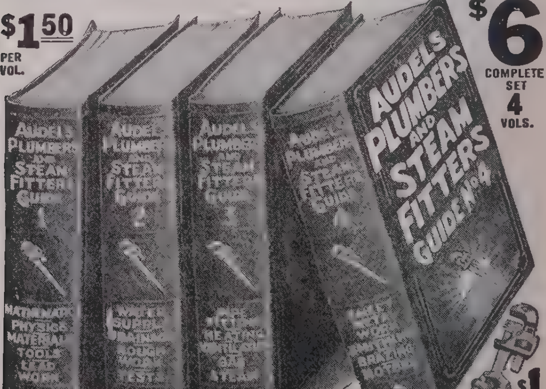
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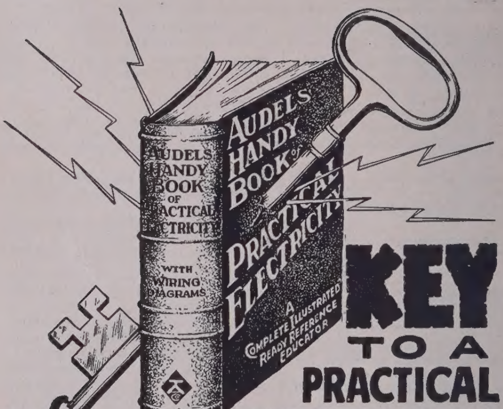
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